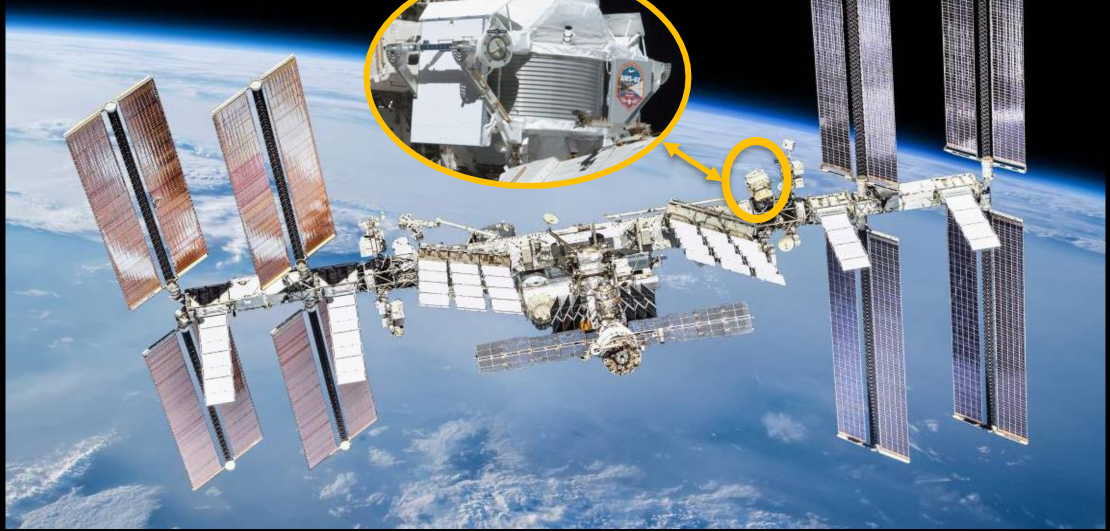
从太空到地下：粒子追踪之旅

贾怡，IHEP

400km above the Earth



July 1, 2025

Neutrino Summer School
@ JUNO site

Education and Work Experience

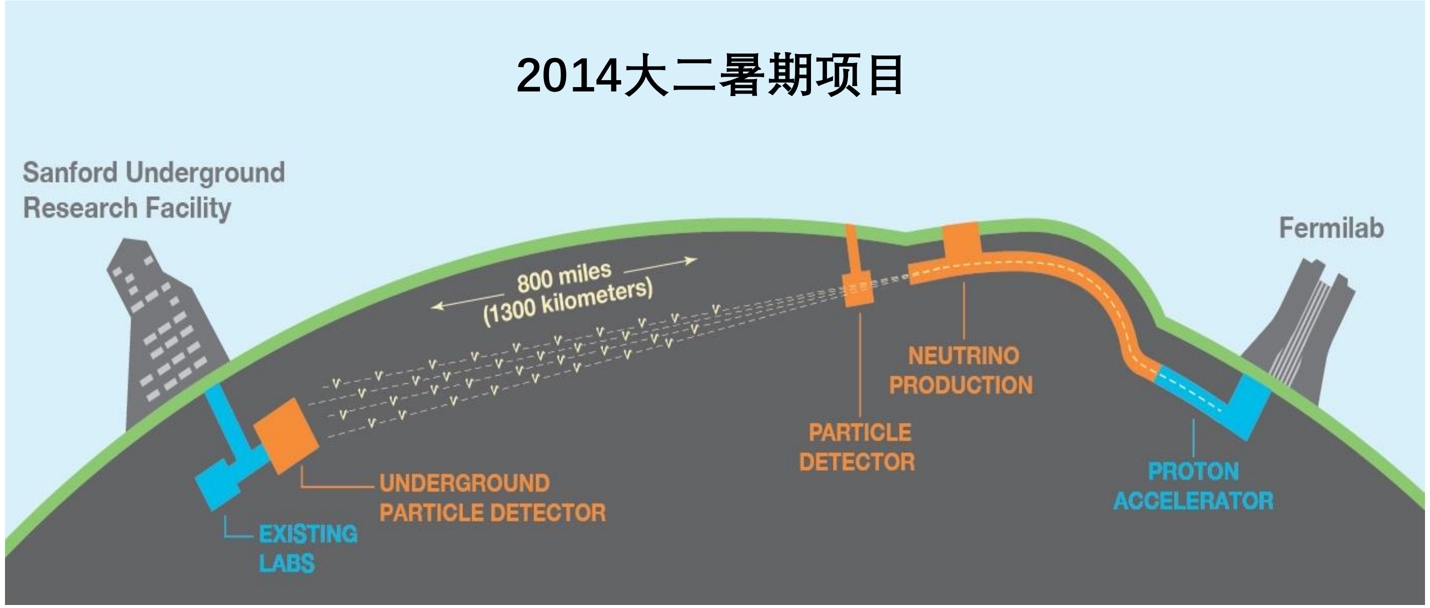
2024 Christmas Party at CERN

2012-09 至 2016-06，	西安交通大学 XJTU	Physics，	B.S.
2016-08 至 2018-08，	MIT，	Physics，	Ph.D.
2018-09 至 2022-03，	MIT，	Postdoctoral Associate	
2022-04 至2025-05，	MIT，	Research Scientist	
2025-05 至今	IHEP	Associate Professor	

In 2017, I joined AMS (阿尔法磁谱仪) as a graduate student under the supervision of Professor Samuel Ting (丁肇中) at MIT. After almost ten years abroad, I decided to return to China and join JUNO as a faculty member at IHEP.

Undergraduate Research Training

I found my interest in particle physics at an early stage.



Worked with Prof. John LoSecco on the Long Baseline Neutrino Experiment (LBNE) in Notre Dame University for a summer

LBNE was renamed to Deep Underground Neutrino Experiment (DUNE) in 2015

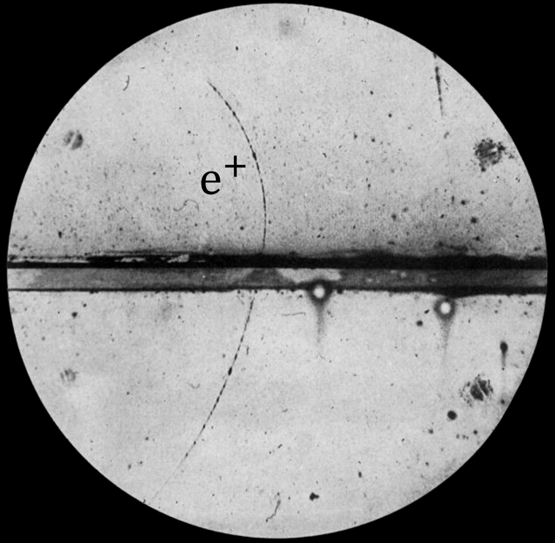
Worked with Prof. Clark McGrew on T2K in Stony Brook University.

Prof. LoSecco and Prof. McGrew helped me apply graduate schools in US.

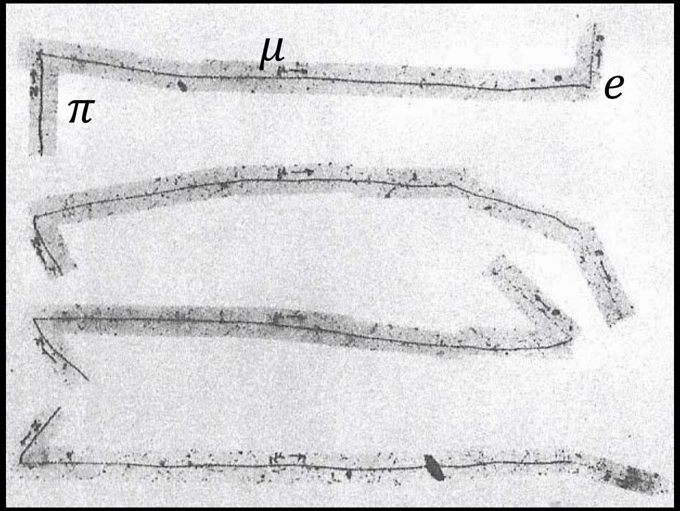
Brief Introduction of Cosmic Rays and Particle Physics

Cosmic Ray and Particle Physics

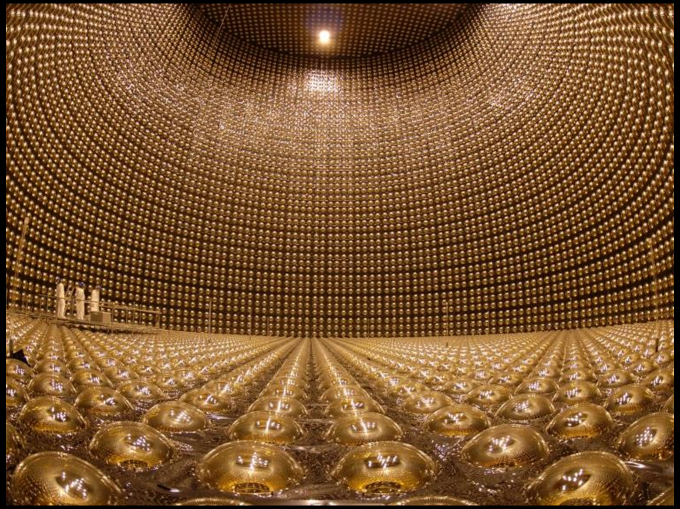
The measurement of charged cosmic rays marked the beginning of modern particle physics research. The study of cosmic rays continues to play a central role in exploring fundamental questions in astrophysics and particle physics.



1932 Discovery of Positron
Nobel Prize (1933) Carl Anderson



1947 Discovery of Pion
Nobel Prize (1950) Cecil Powell



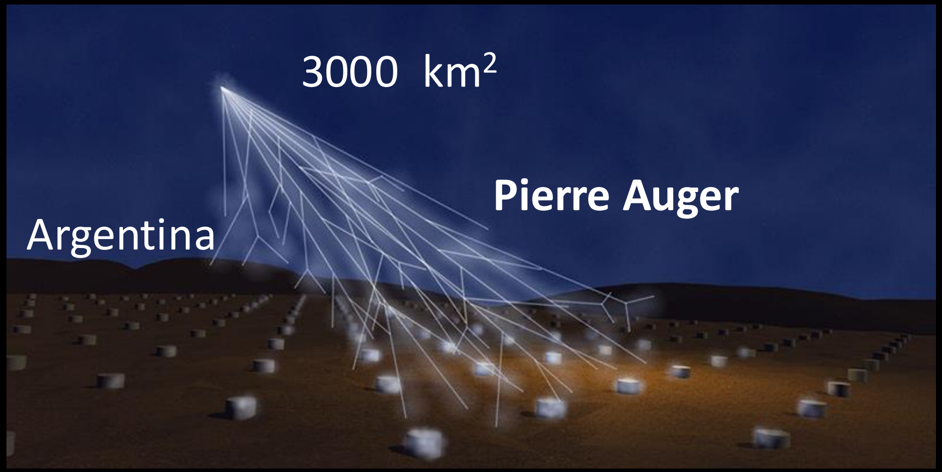
1987 Discovery of Supernova Neutrino
Nobel Prize (2002) Raymond Davis, Masatoshi Koshiba

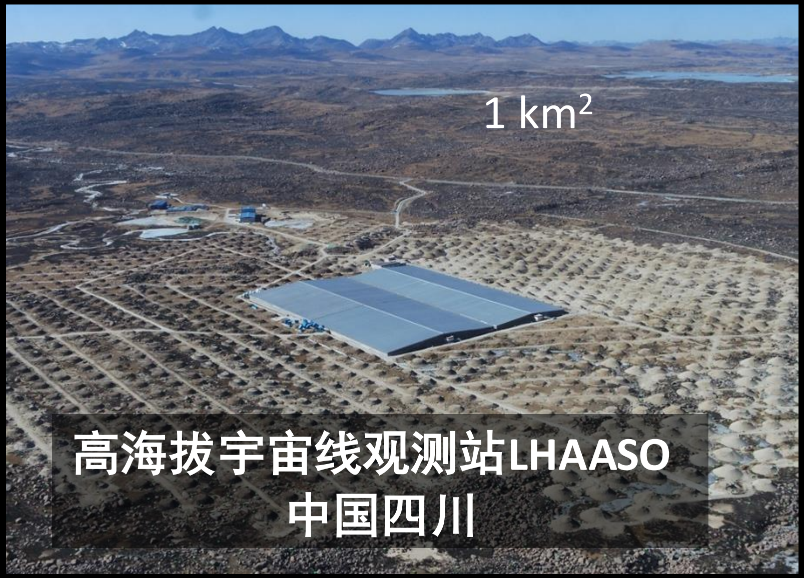
- 1936: Muon (μ)
- 1949: Kaon (K)
- 1949: Lambda (Λ)
- 1952: Xi (Ξ)
- 1953: Sigma (Σ)

Neutrinos, as neutral and weakly interacting particles, have emerged as a new cosmic messenger, enabling us to probe otherwise inaccessible regions of the Universe.

Charged Cosmic rays(89% protons, 10% helium, 1% heavier nuclei + electrons)

e.g.： Ground-based high-energy cosmic ray experiments：

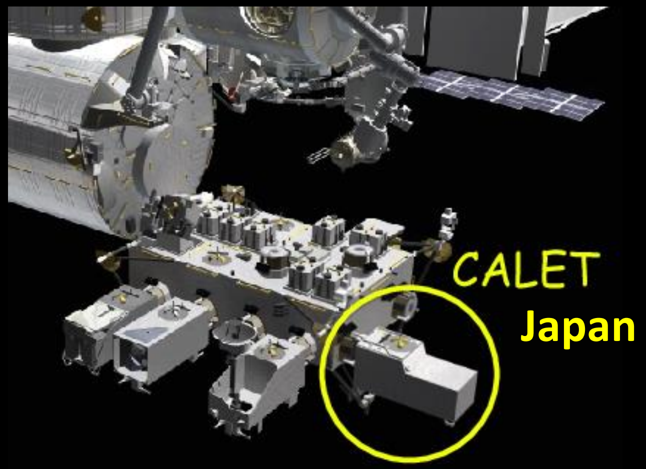




Cosmic ray measurements in space

“悟空” DAMPE

阿尔法磁谱仪AMS

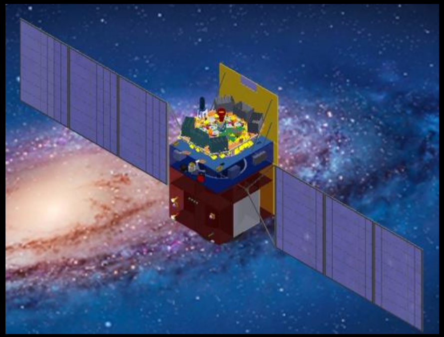


Neutral cosmic rays

Photons

500米口径球面射电望远镜
“天眼” （FAST），中国贵州

“慧眼”（HXMT）

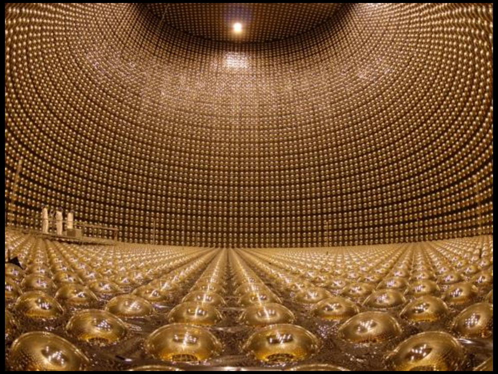


James Webb Space Telescope

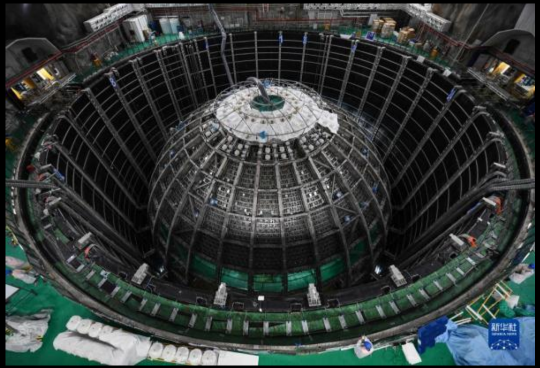
Fermi

Neutrinos

IceCube



Super-Kamiokande



JUNO

Charged cosmic rays and high energy photons are major concerns for radiation damage

Neutrinos are harmless

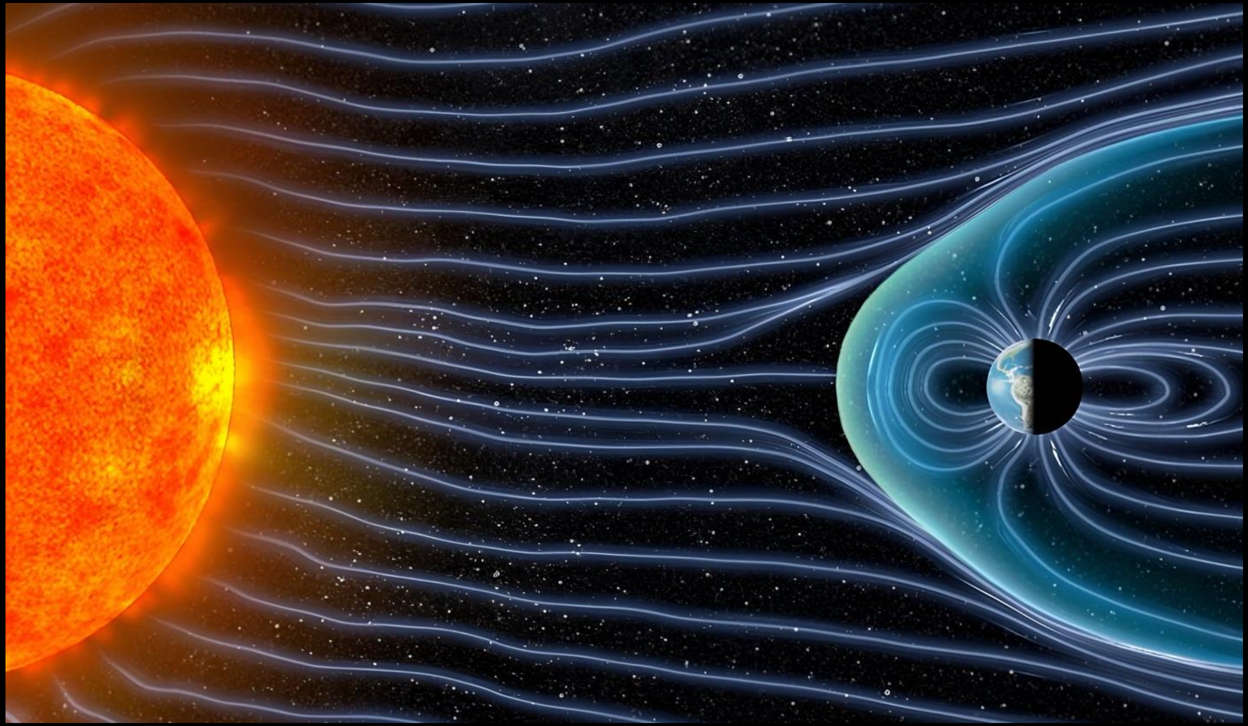
Cosmic radiation from the Milky Way: 90 rem/year

The lethal dose is about 300 rem

long-term base on the Moon or Mars

Earth Protections from Charged Cosmic Rays

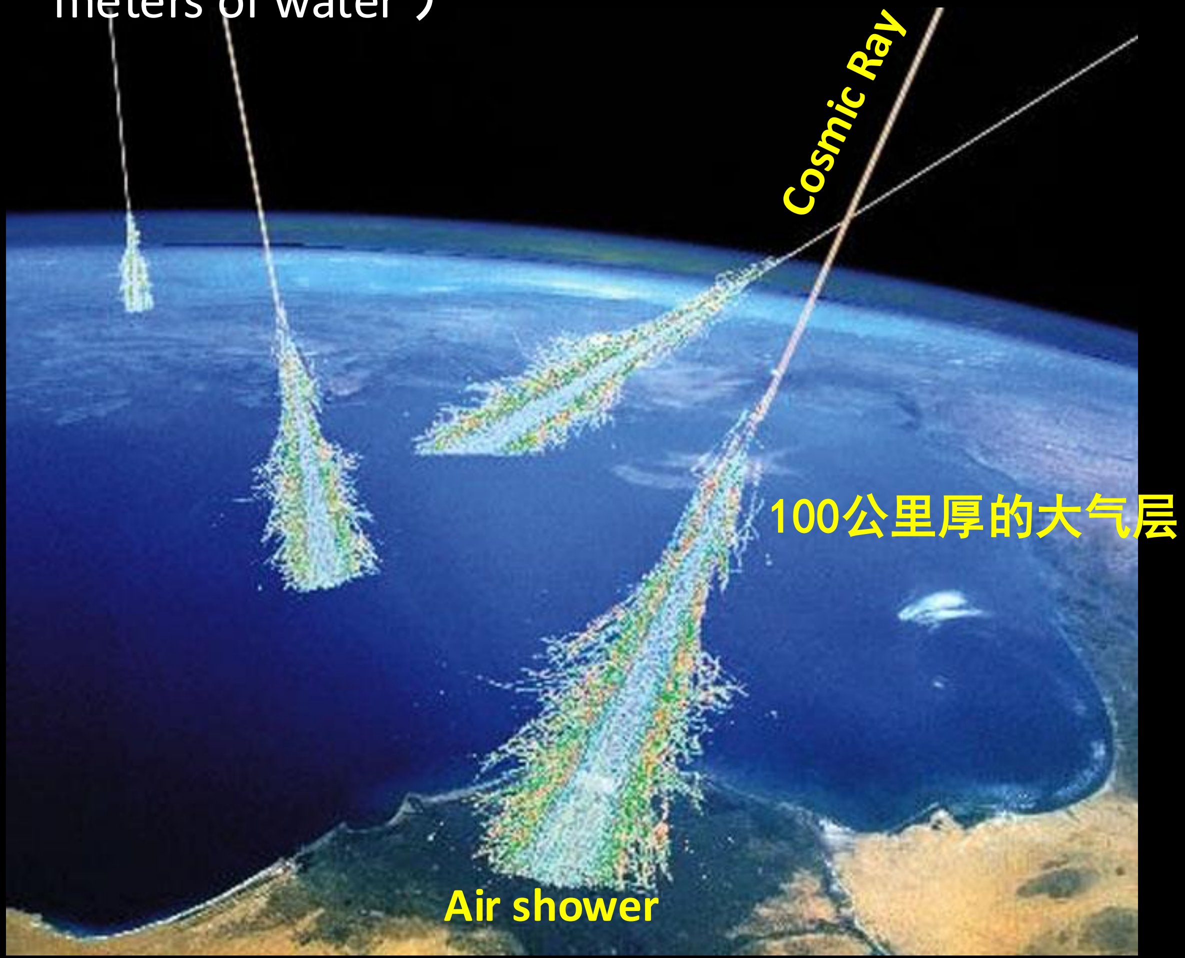
geomagnetic deflection



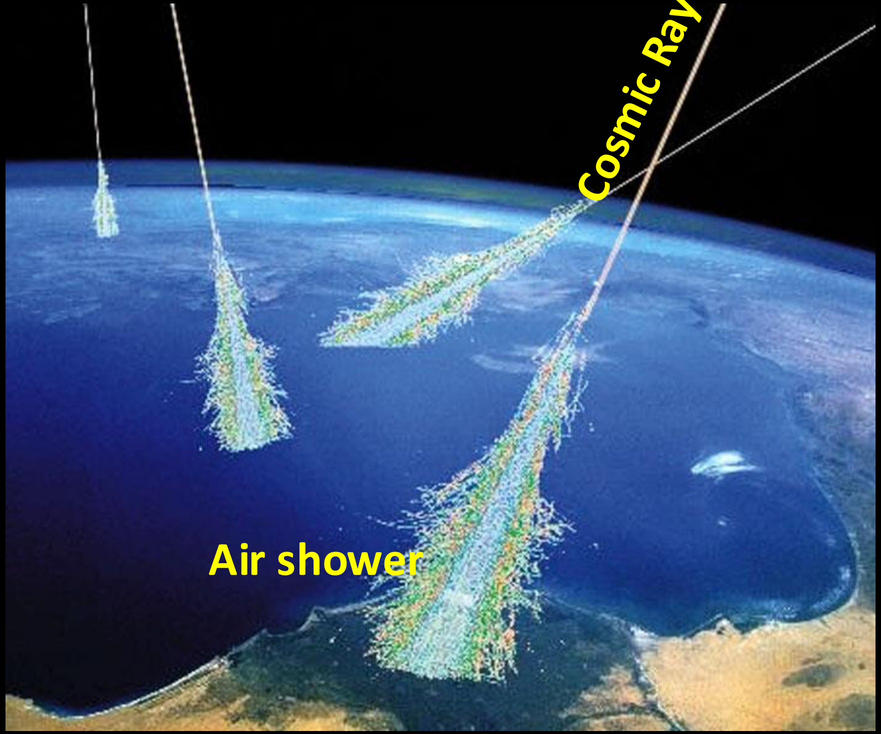
No geomagnetic field/atmosphere
-> no human being!

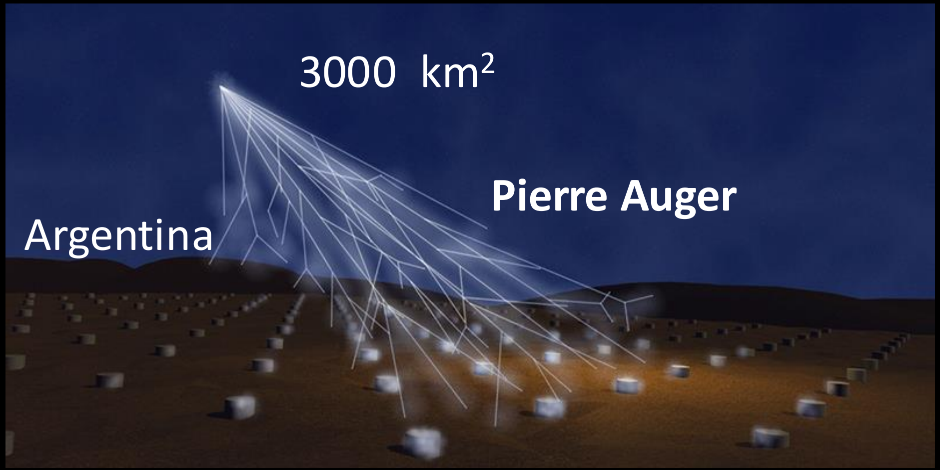
atmospheric shielding

Charged cosmic rays are absorbed by the Earth's 100-km-thick atmosphere（10 meters of water ）



Measurement of Charged Cosmic rays in Space

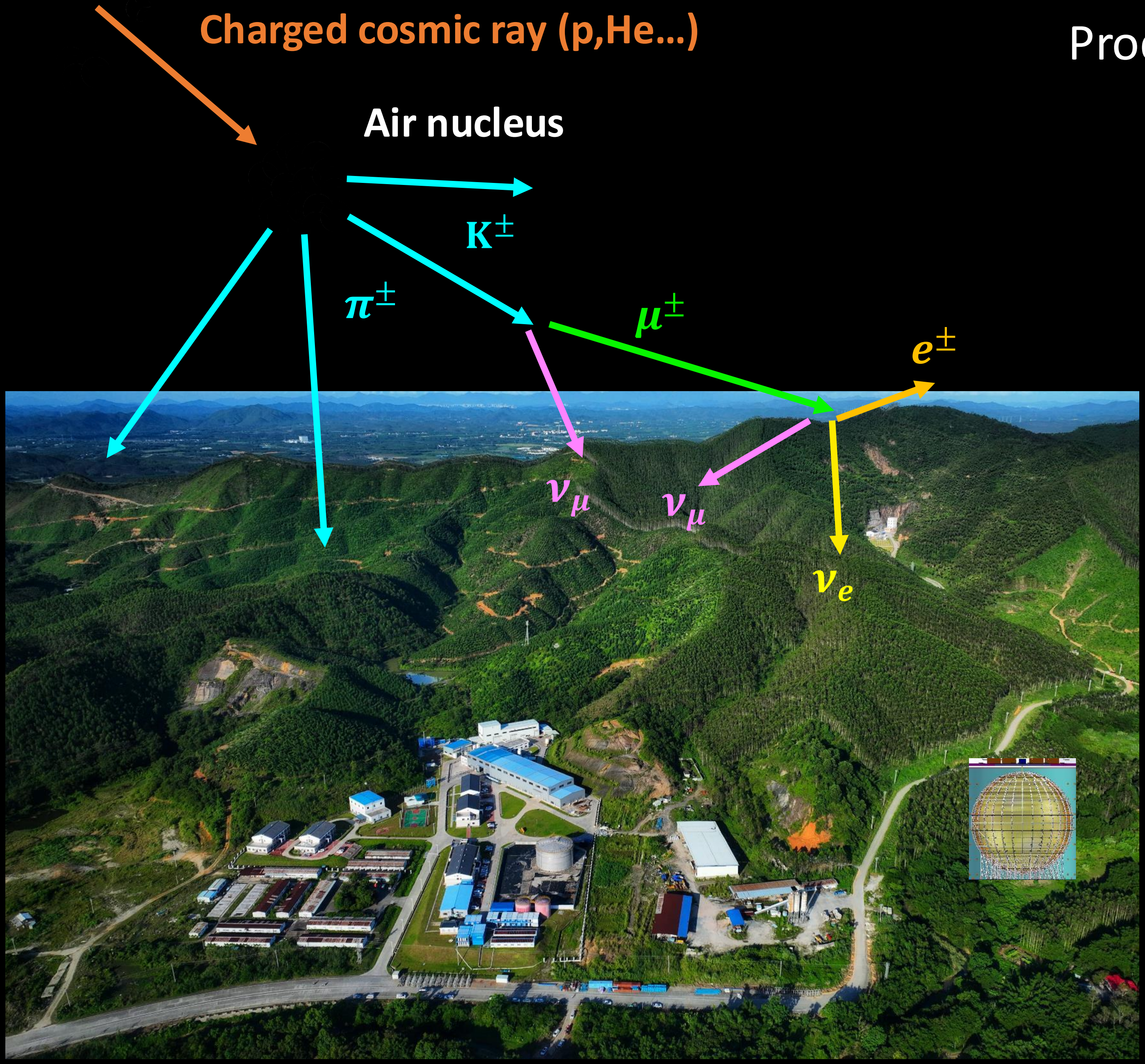




Advantage: Avoid large systematic errors induced by air shower

Disadvantage: Much smaller acceptance

Atmospheric Neutrinos from Charged Cosmic Rays



Production of atmospheric neutrino:

$$\begin{array}{l} \pi^+ \longrightarrow \mu^+ + \nu_\mu \\ \qquad\quad\ \ \downarrow \\ \qquad\quad\ \ e^+ + \nu_e + \bar{\nu}_\mu \end{array}$$

$$\begin{array}{l} \pi^- \longrightarrow \mu^- + \bar{\nu}_\mu \\ \qquad\quad\ \ \downarrow \\ \qquad\quad\ \ e^- + \bar{\nu}_e + \nu_\mu \end{array}$$

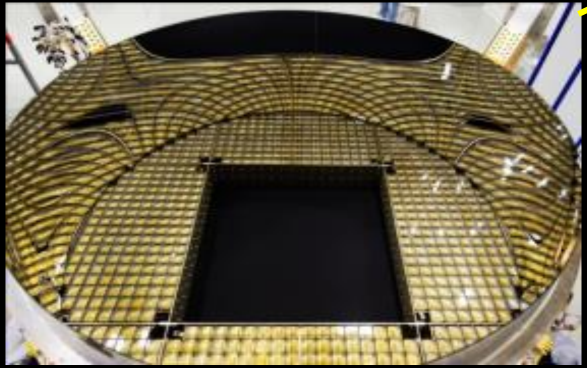
1998 Discovery of Neutrino oscillation in atmospheric neutrino
Nobel Prize (2015) Takaaki Kajita (Super-K)

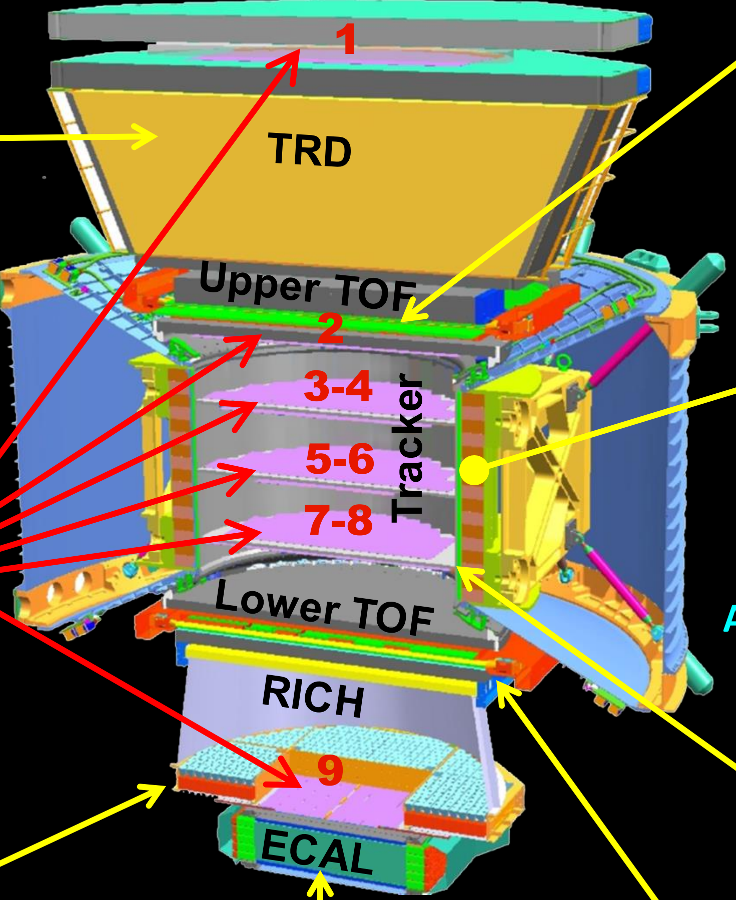
AMS is a space version of a precision detector used in accelerators

Transition Radiation Detector (TRD)
identify e^+, e^-

Silicon Tracker
measure Z, P

Ring Imaging Cerenkov (RICH)
measure Z, E





Electromagnetic Calorimeter (ECAL)
measure E of e^+, e^-

Upper TOF measure Z, E

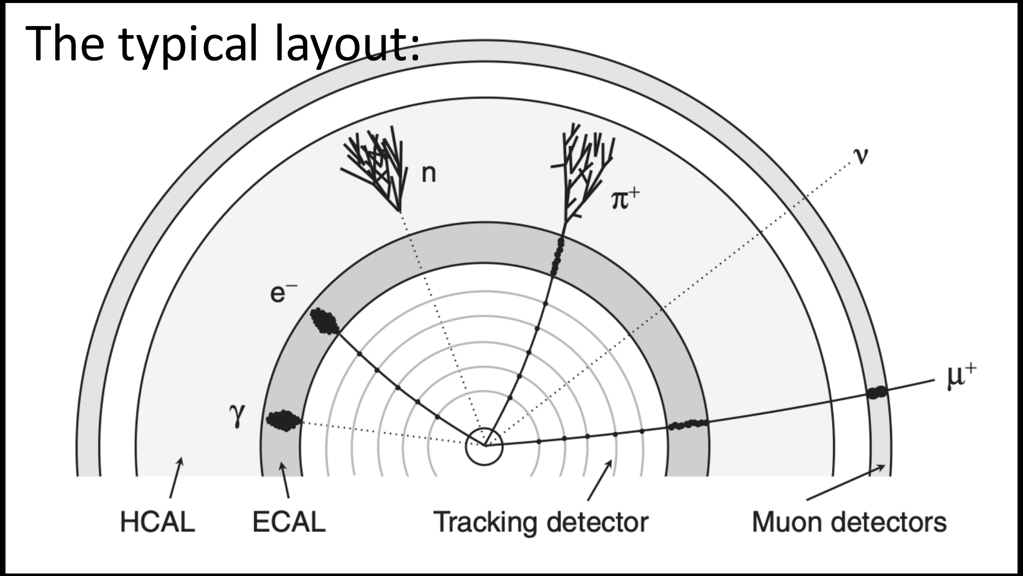
Magnet identify ±Z, P

Anticoincidence Counters (ACC)
reject particles from the side

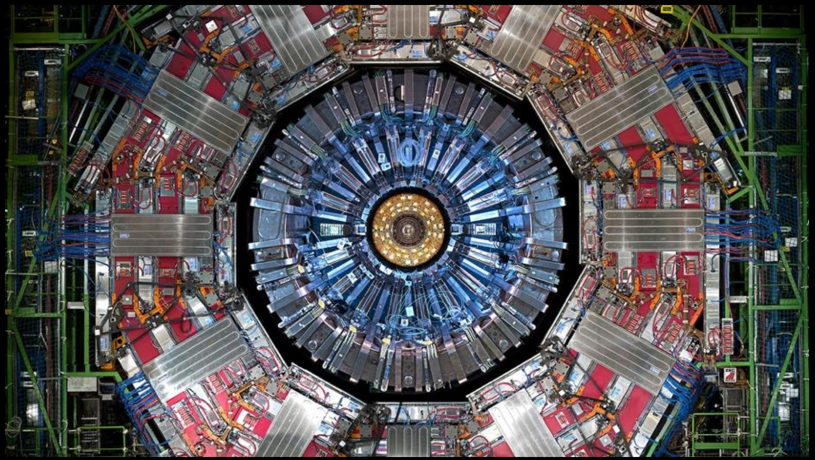
Lower TOF measure Z, E

Accelerator Type Experiment

Human-made collisions, test standard model or beyond

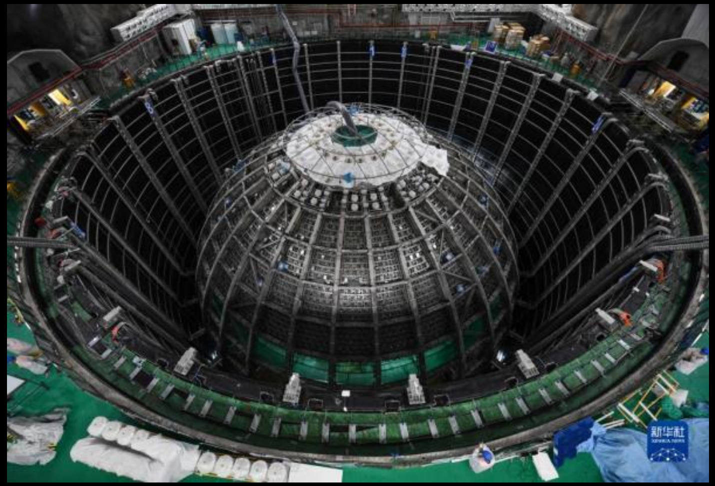


e.g., CMS at LHC

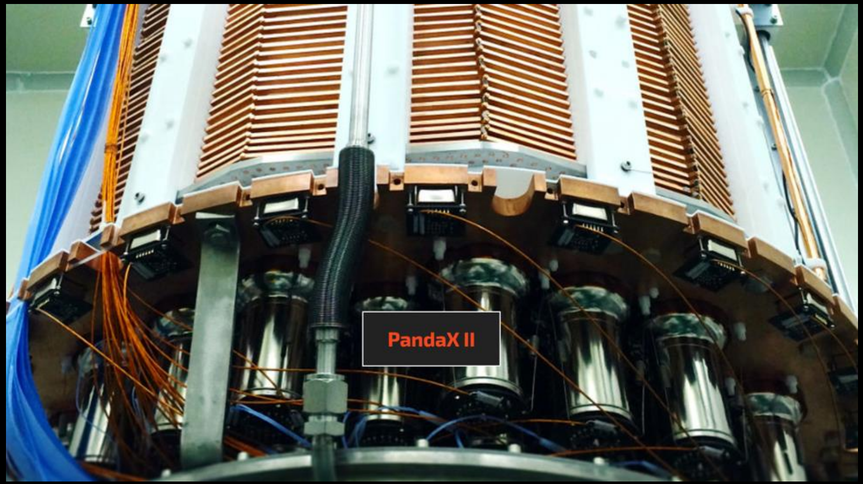


Non-accelerator Type Experiment

Natural sources, study rare natural processes (neutrinos, dark matter…)

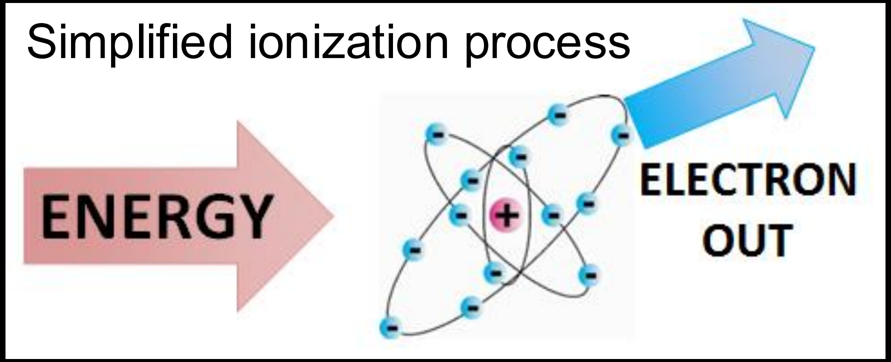


PandaX 四川锦屏



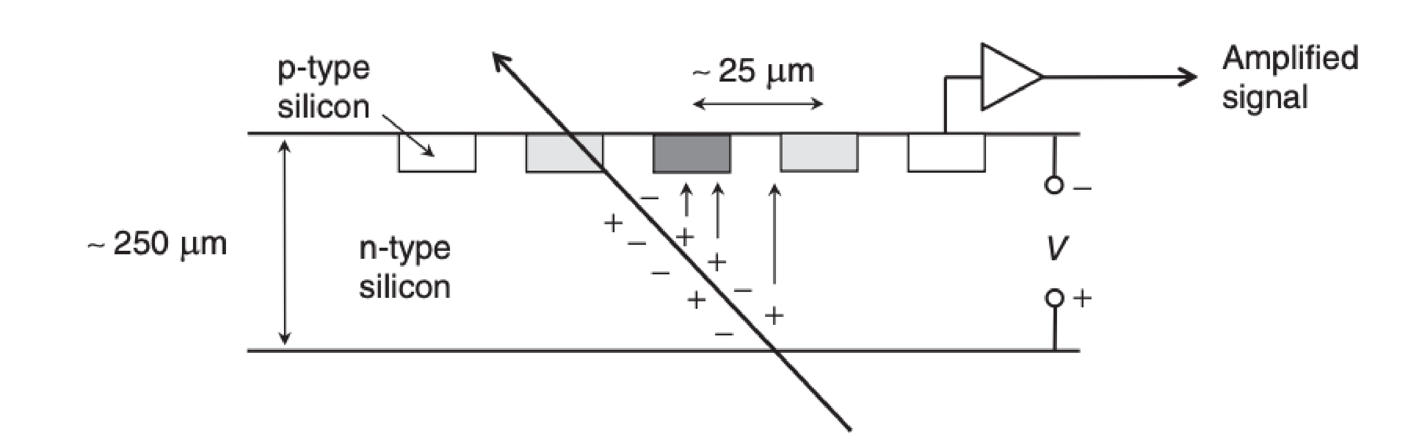
Particle energy deposition in matter

When a relativistic charged particle passes through a medium, it interacts electro-magnetically with the atomic electrons and loses energy through the ionization of the atoms.

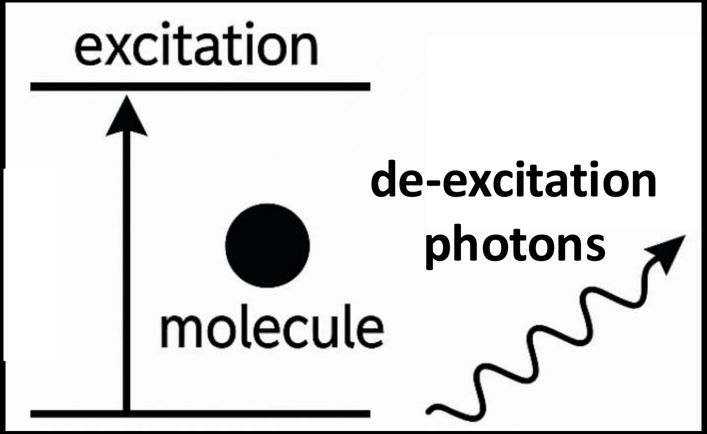


Particle energy deposition is the basis of nearly all high energy physics detector. Different types of detectors "read out" this deposited energy through various physical mechanisms:

p-n junction in a semiconductor detector

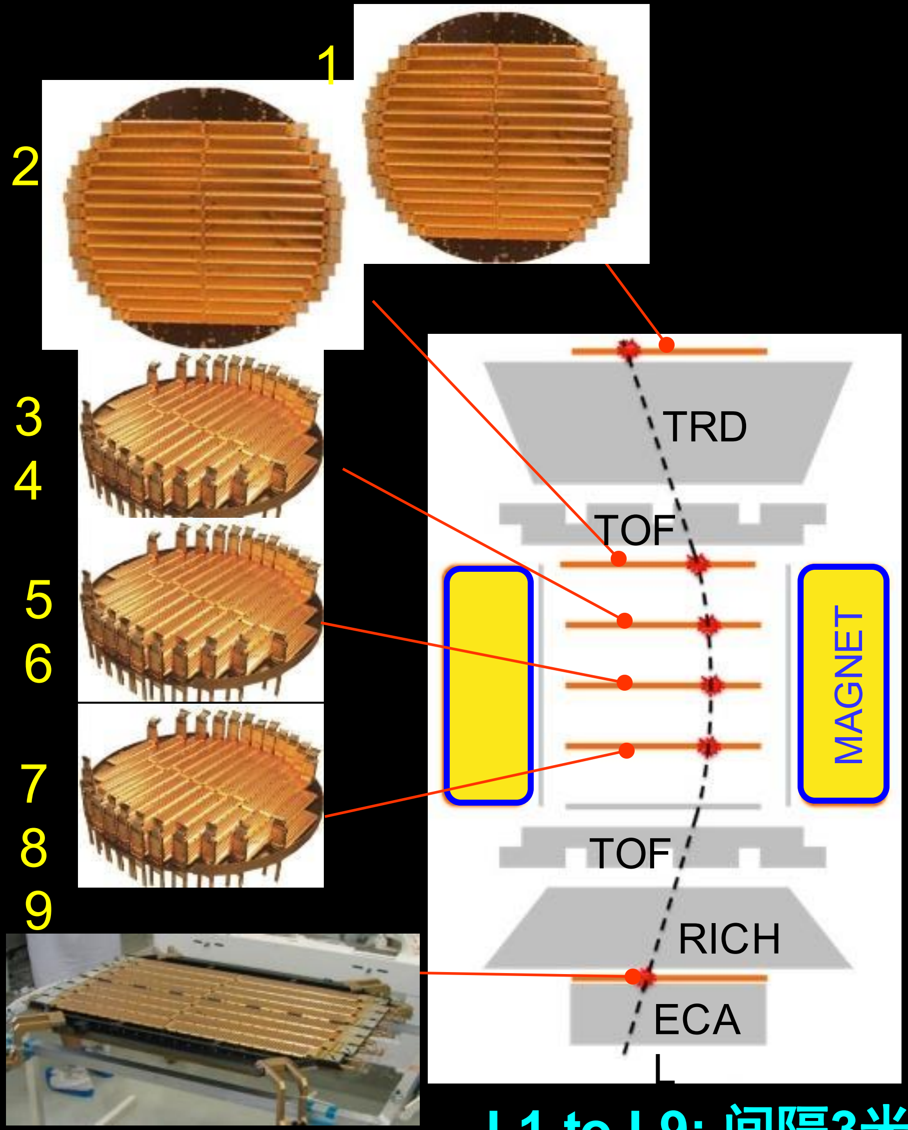


Scintillation detector



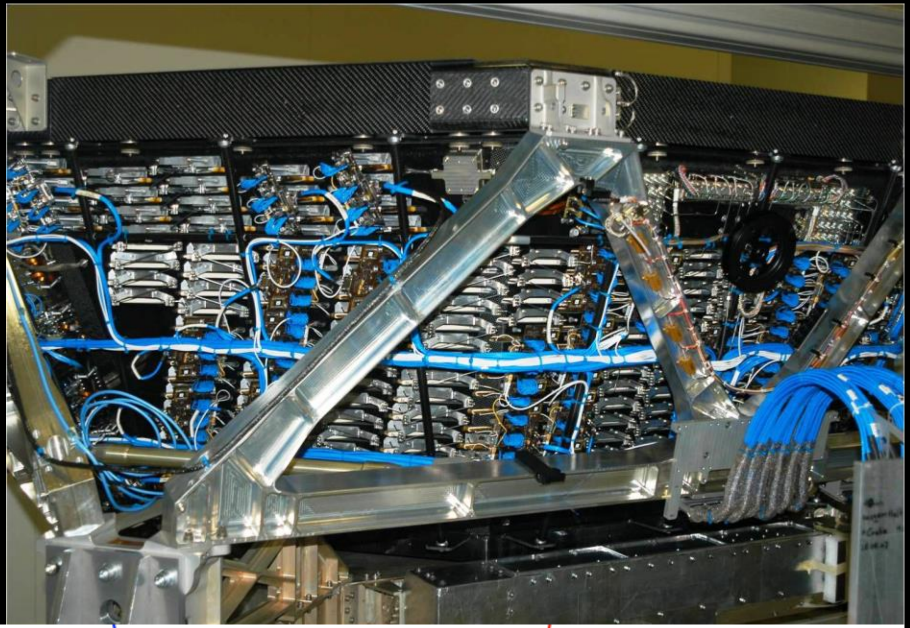
Common Detector Type

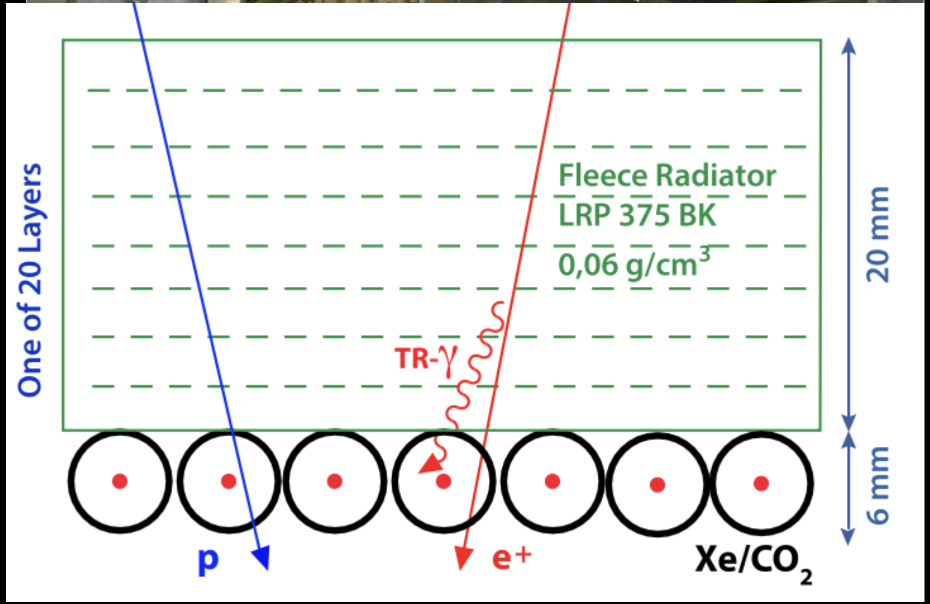
Semiconductor Detector:
e.g., AMS Silicon Tracker



L1 to L9: 间隔3米

Gaseous Detector:
e.g., AMS Transition Radiation Detector



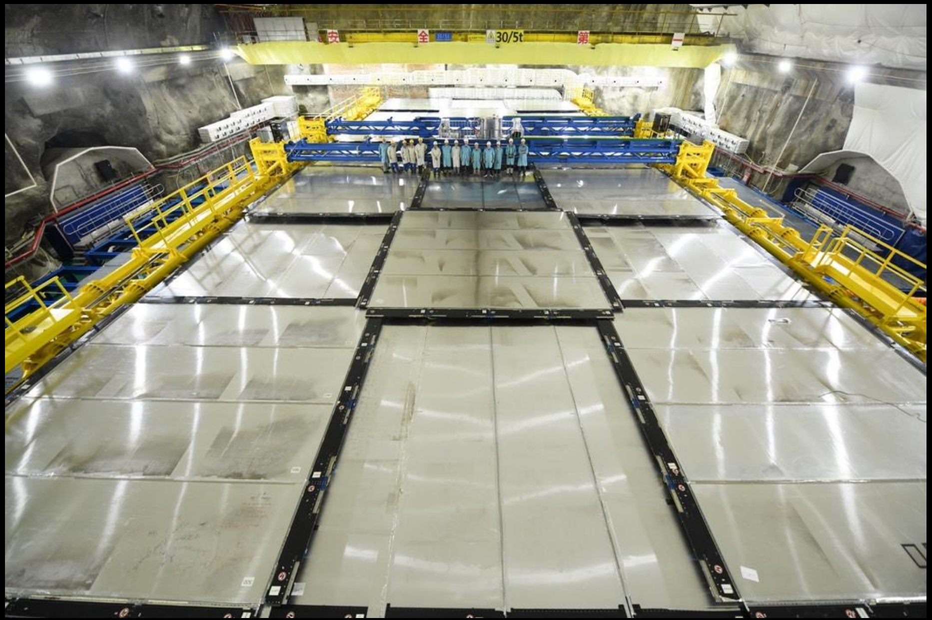


Common Detector Type: Scintillation Detector

Examples of Plastic Scintillator:

AMS Time of Flight (TOF) Counts

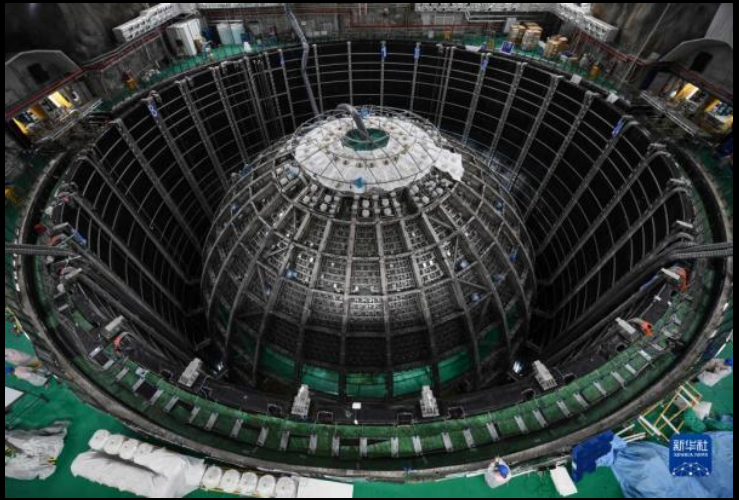
JUNO Top Tracker



Examples of Liquid Scintillator:

	Target mass	Energy resolution at 1 MeV
Daya Bay	20 ton	8%
Borexino	300 ton	5%
KamLAND	1000 ton	6%
JUNO	20 000 ton	3%

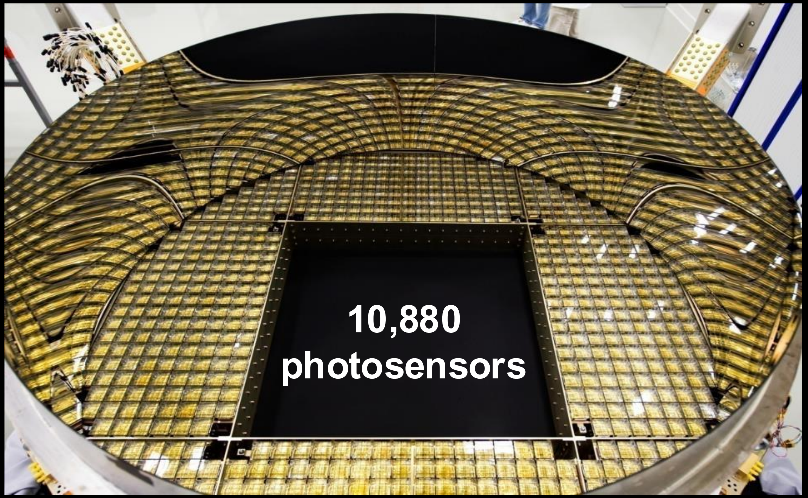
Largest of its kind!

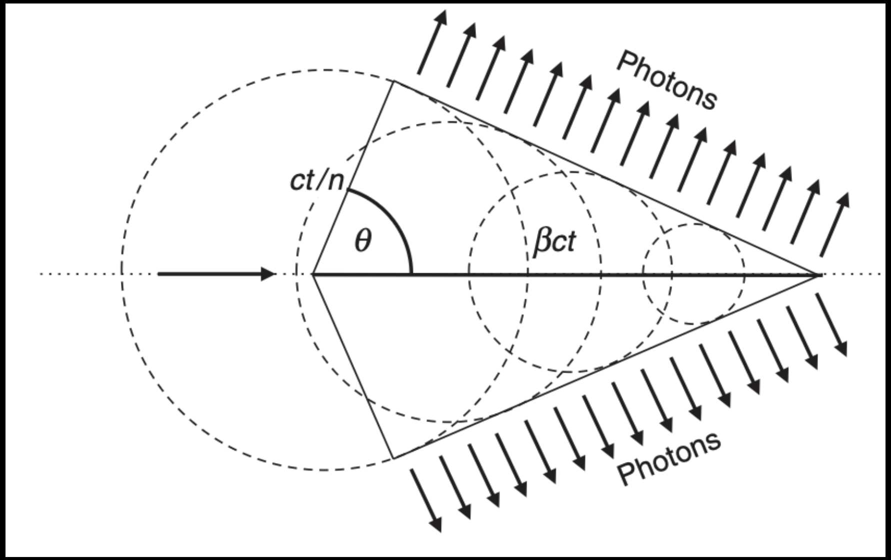


Common Detector Type: Cherenkov Detector

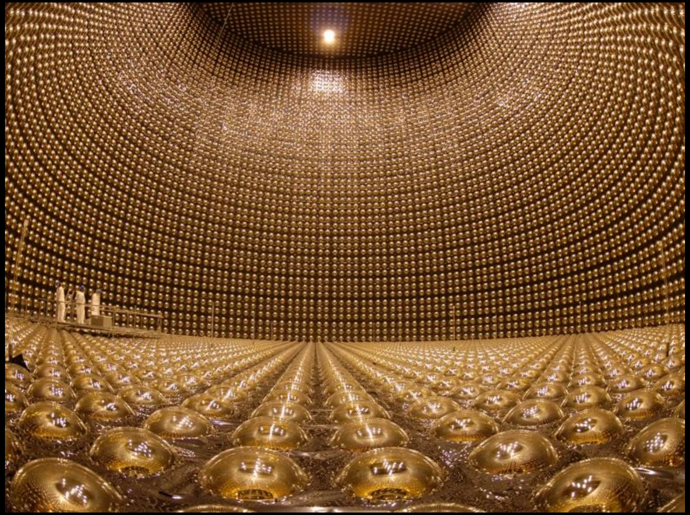
If the velocity of the particle is greater than the speed of light in the medium, Cherenkov light is emitted.

AMS Ring Imaging Cerenkov (RICH) detector





Super-Kamiokande



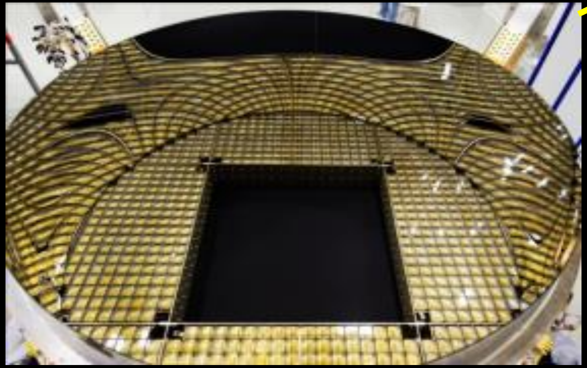
IceCube

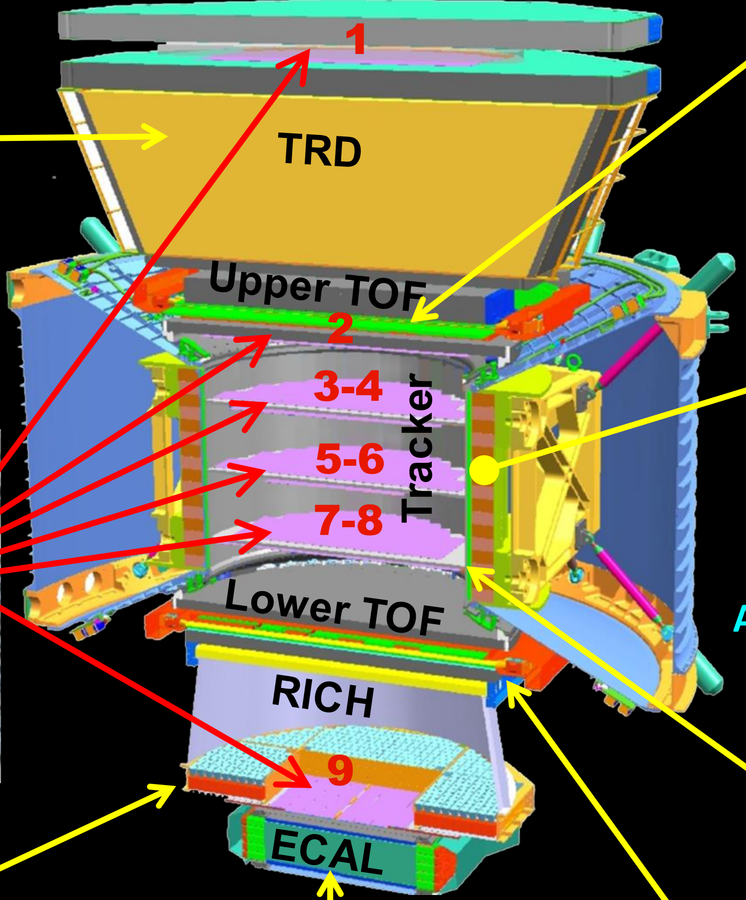
AMS is a space version of a precision detector used in accelerators

Transition Radiation Detector (TRD)
identify e^+, e^-

Silicon Tracker
measure Z, P

Ring Imaging Cerenkov (RICH)
measure Z, E





Electromagnetic Calorimeter (ECAL)
measure E of e^+, e^-

Upper TOF measure Z, E

Magnet identify ±Z, P

Anticoincidence Counters (ACC)
reject particles from the side

Lower TOF measure Z, E

PhD work

Charge Calibration of AMS Tracker

Undergraduate Research Training at IHEP

大三暑期科研项目:

JUNO太阳中微子灵敏度研究
指导老师：李玉峰，曹俊

Measurement of solar hep Neutrino with JUNO

Yi Jia
Advisor: Yufeng Li, Jun Cao
Xi'an Jiaotong University, Shaanxi, China
Institute of High Energy Physics, Beijing, China

July 30, 2015

Abstract

The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose neutrino experiment proposed in 2008. In this technical note, a probability for JUNO to measurement the *hep* neutrinos has been explored. By applying the predicted flux in the solar model BSB05(GS98), the expected spectra for both signal and background at JUNO can be obtained by integrating the flux at different neutrino energy. For background, ^8B and atmosphere neutrinos are analyzed, while further backgrounds will be included in the future. Finally, we show a test of fit to reach the upper bound of *hep* flux.

大四毕业设计:

下一代无中微子双beta衰变探测器nEXO的设计
指导老师：温良剑

西安交通大学本科毕业设计（论文）2016

Title: Study of the performance of nEXO detector
name: Jia Yi
Supervisor: Wen Liangjian, Zhang Ying

ABSTRACT

nEXO experiment is an update of EXO-200 in the future. It aims to search for neutrinoless double beta decay ($0\nu\beta\beta$), thus determining if neutrino is Majorana fermion as predicted in theory. The study of this paper focuses on the detection of ionized electrons in nEXO detector, and explore how the strength of electric field in detector impacts the process of data analysis. First, we can deduce the mathematical form of transform function according

Undergraduate research training is a great way to prepare for graduate school. You never know, your advisor might one day become your colleagues!

How to reach us: Talking face to face is most effective, but an email is good enough!

Graduation in Two Years

PHYSICS GRAD STUDENT PROGRESS REPORT

FULL NAME: Jia, Yi
MIT ID: 915897902
ENTRY DATE: 9/1/2016 **YEARS AT MIT:** 1.7
ADVISOR: Roland, Gunther
SUPERVISOR: Ting, Samuel
RES. AREA: NUPAX
STATUS: Current

PROGRESS SNAPSHOT

BREADTH COMPLETED	Y
SPECIALTY COMPLETED	Y
WRITTEN COMPLETED	Y
ORAL COMPLETED	Y
THESIS COMPLETED	N

BREADTH COURSES

2017SP	8.323	Rel Quantum Field Theory I	A
2017SP	8.821	String Theory	A

SPECIALTY COURSES

2017FA	8.811	A
2017SP	8.711	A

PART I

WRITTEN EXAM/ SUBSTITUTIONS

CM	YS	SM	Y
EM	Y	QM	YS

ORAL GENERAL EXAM

2017/12	Pass	NUPAX

**Note: YS means that the requirement was satisfied by passing the relevant course with at least B+*

Passed SM (统计力学) and EM (电磁学) before the courses

One year to take 6 courses：

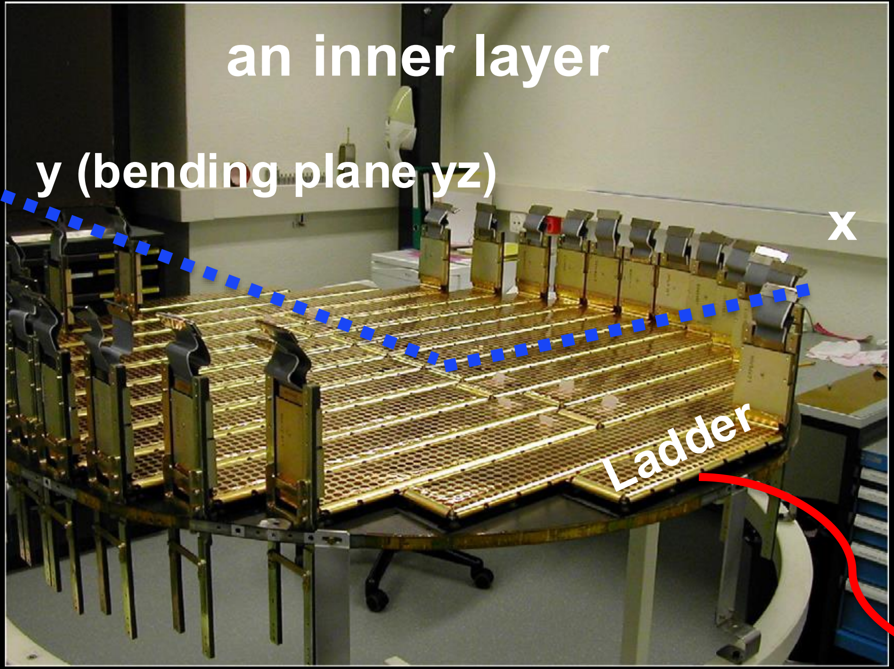
CM (经典力学),
QM(量子力学)

Two Breadth courses：
QFT (量子场论)、
String Theory (弦论)

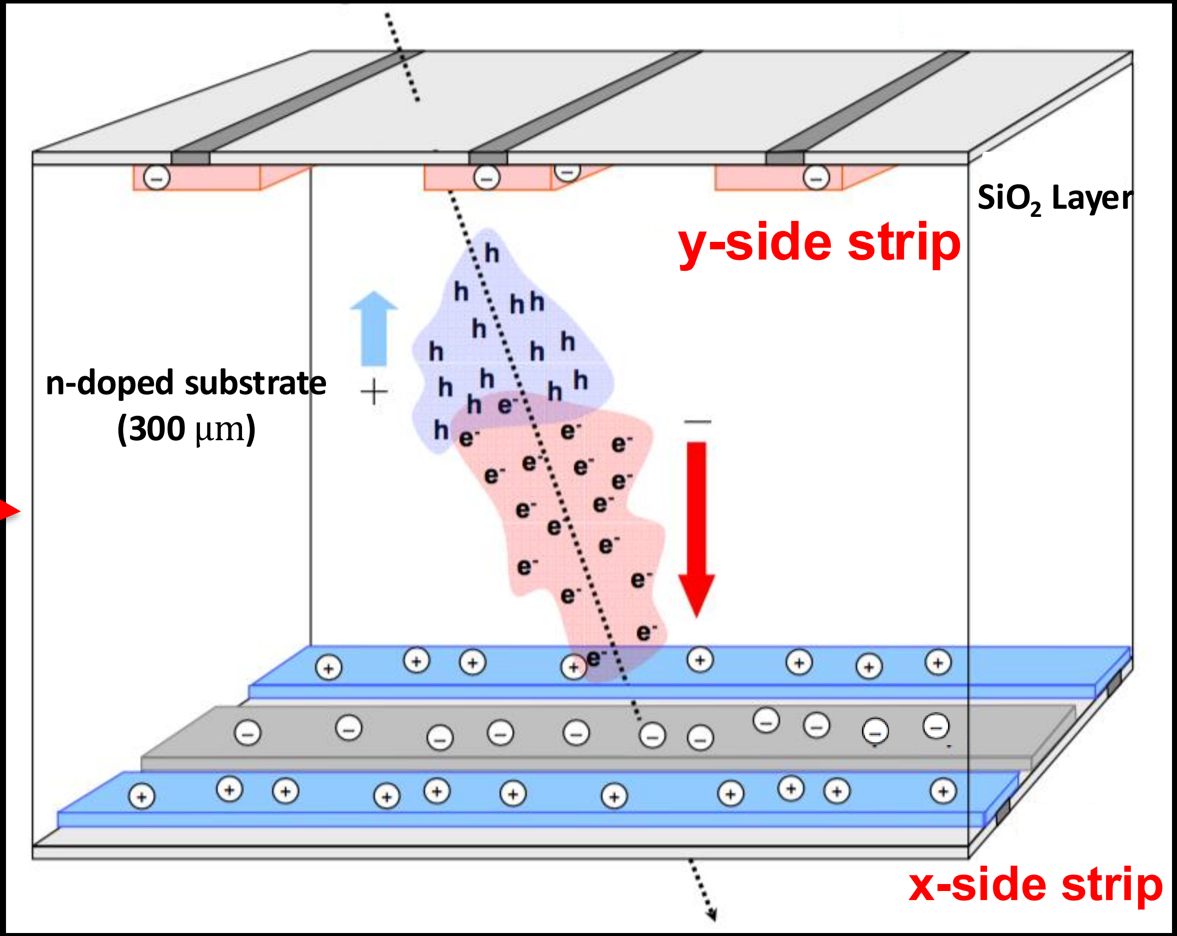
Two Specialty courses:
Particle physics
Nuclear physics

One year for research

AMS Silicon Tracker Calibration



double-sided micro-strip sensor



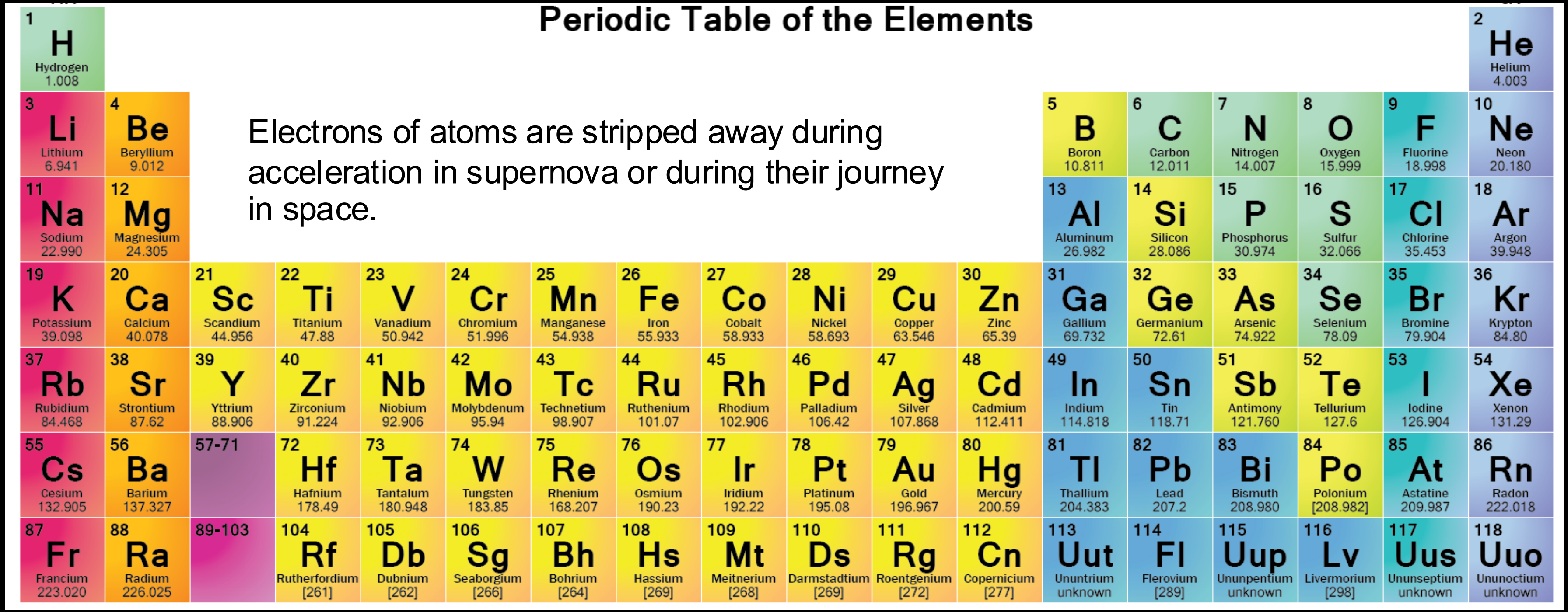
The whole tracker system has **2264 sensors** assembled in **192 ladders**, totaling **~200k readout channels**.

Principle of charge measurement: dE/dx ∝ Z^2 (relativistic particles)

x (y)-side strip in each layer is used to measure particle charge.

Caution on Terminology

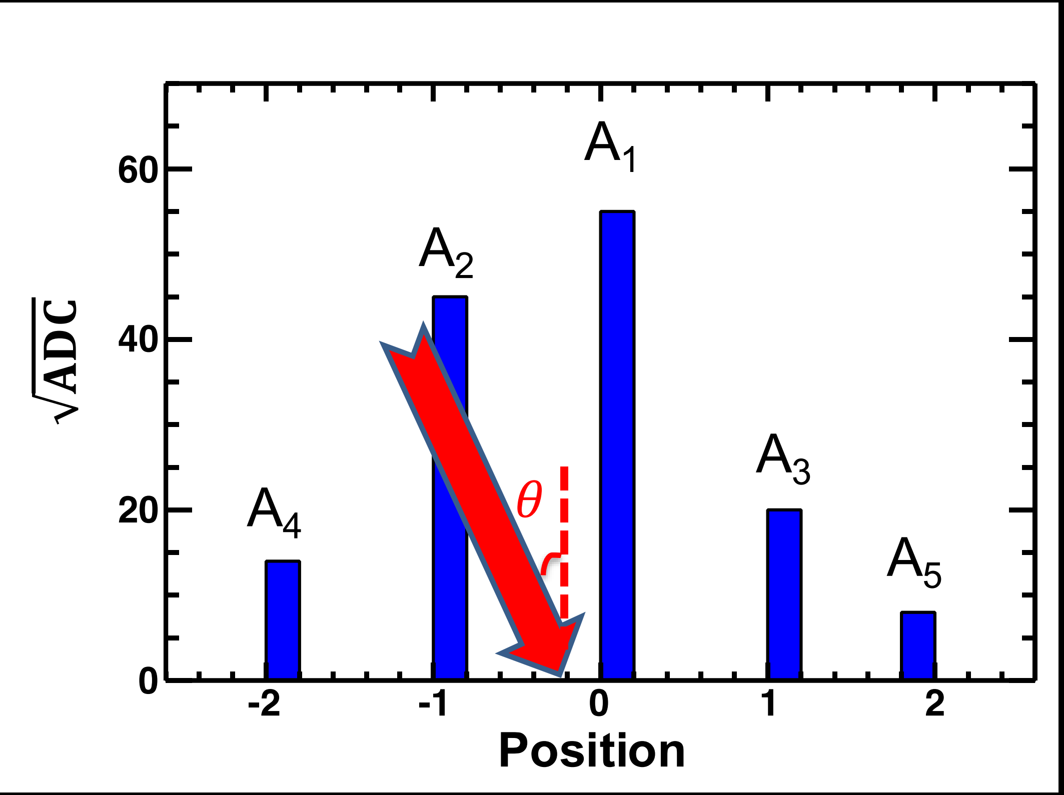
Charge in the context of AMS refers to the electric charge number of a cosmic-ray particle (atomic number 原子序数 for nuclei）.

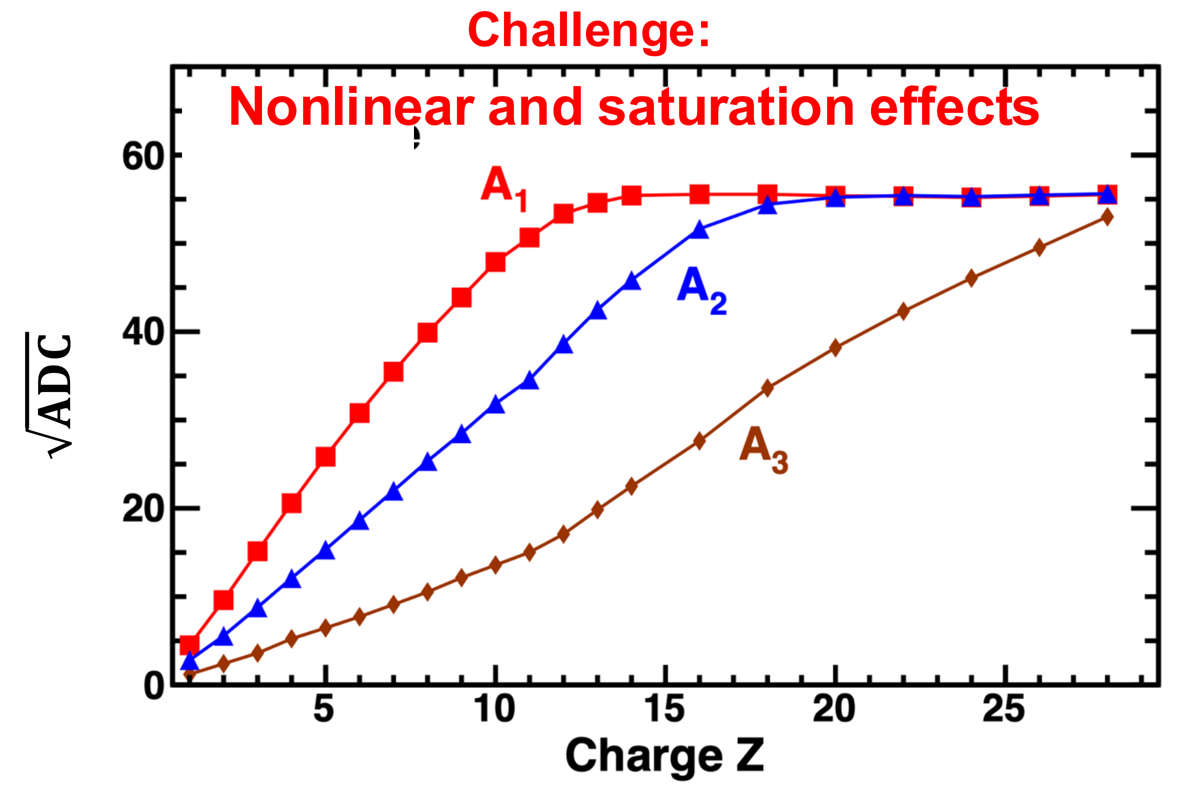


In the context of JUNO, charge refers to the number of photoelectrons collected by PMTs -> energy of neutrinos

Overcoming nonlinear effects with single-strip measurements

A_i(i=1-5) are the strips with five largest signal responses.





Charge resolution is improved by measuring the signal by **individual** strip (A_1, A_2, $A_{3, \ldots}$) instead of using the **sum** of signals from all strips.

Various corrections are needed to obtain the final charge which has **NO dependence on** the **readout electronics, coordinate** (position, inclination θ).

Readout Element Calibration

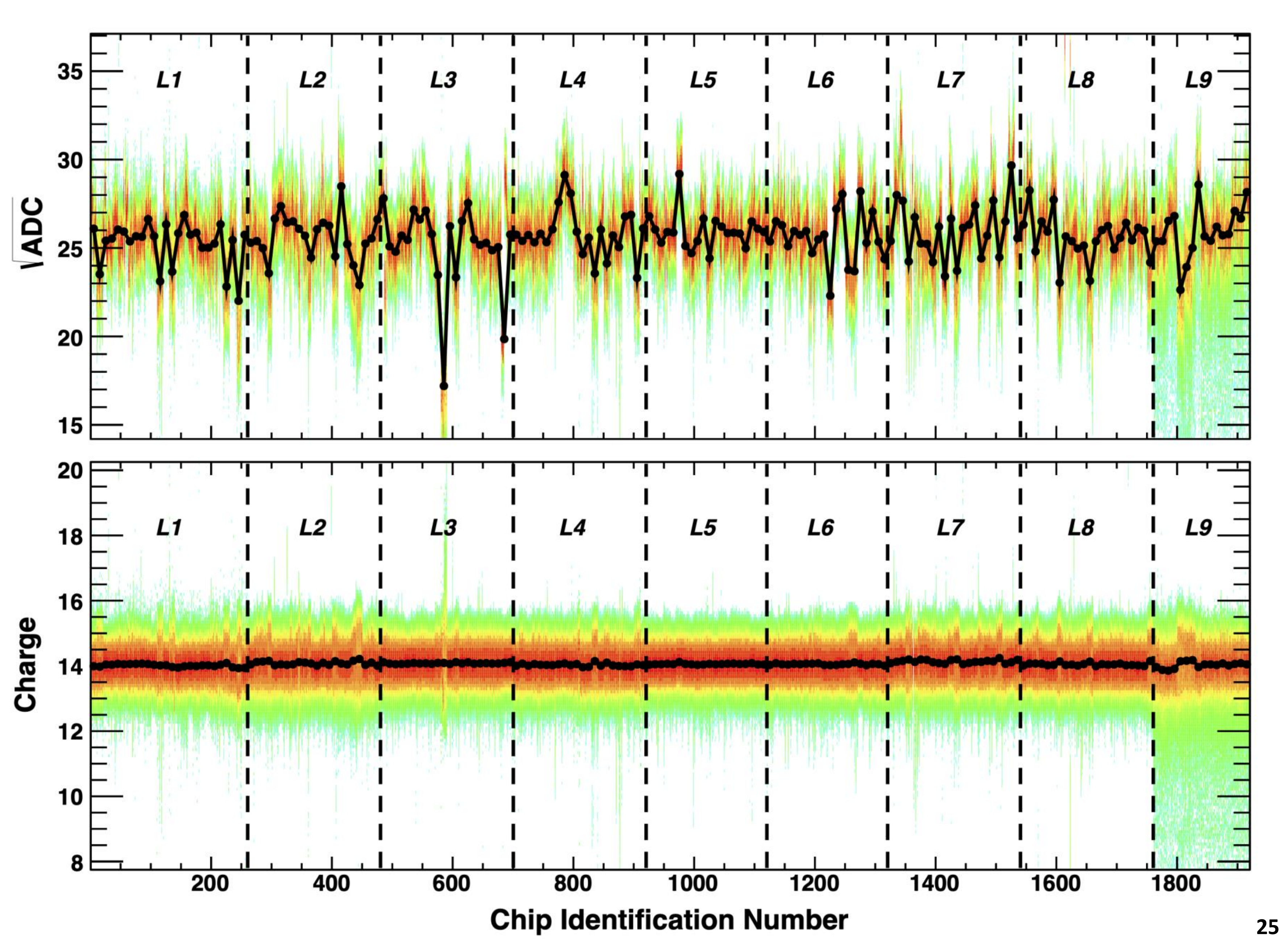
Example of the Results: Silicon (Z=14, selected by TOF scintillation counters) Y-side seed strip **~2000 chips (64 channels each)**

Front-End Electronics

10 Chips y side

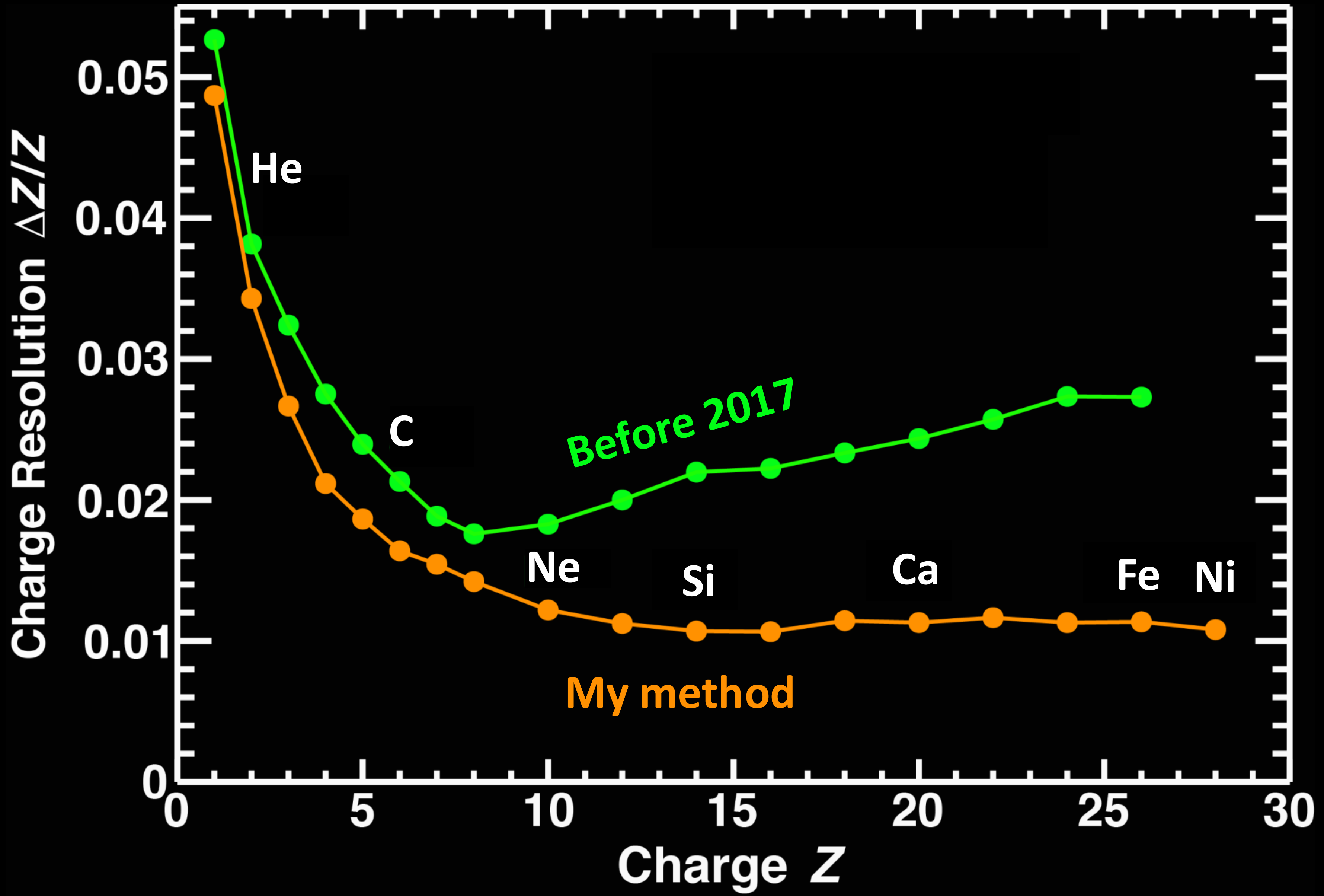
Silicon Sensor

All 200,000 channels of the tracker system are equalized. This procedure makes the responses of detector homogeneous.

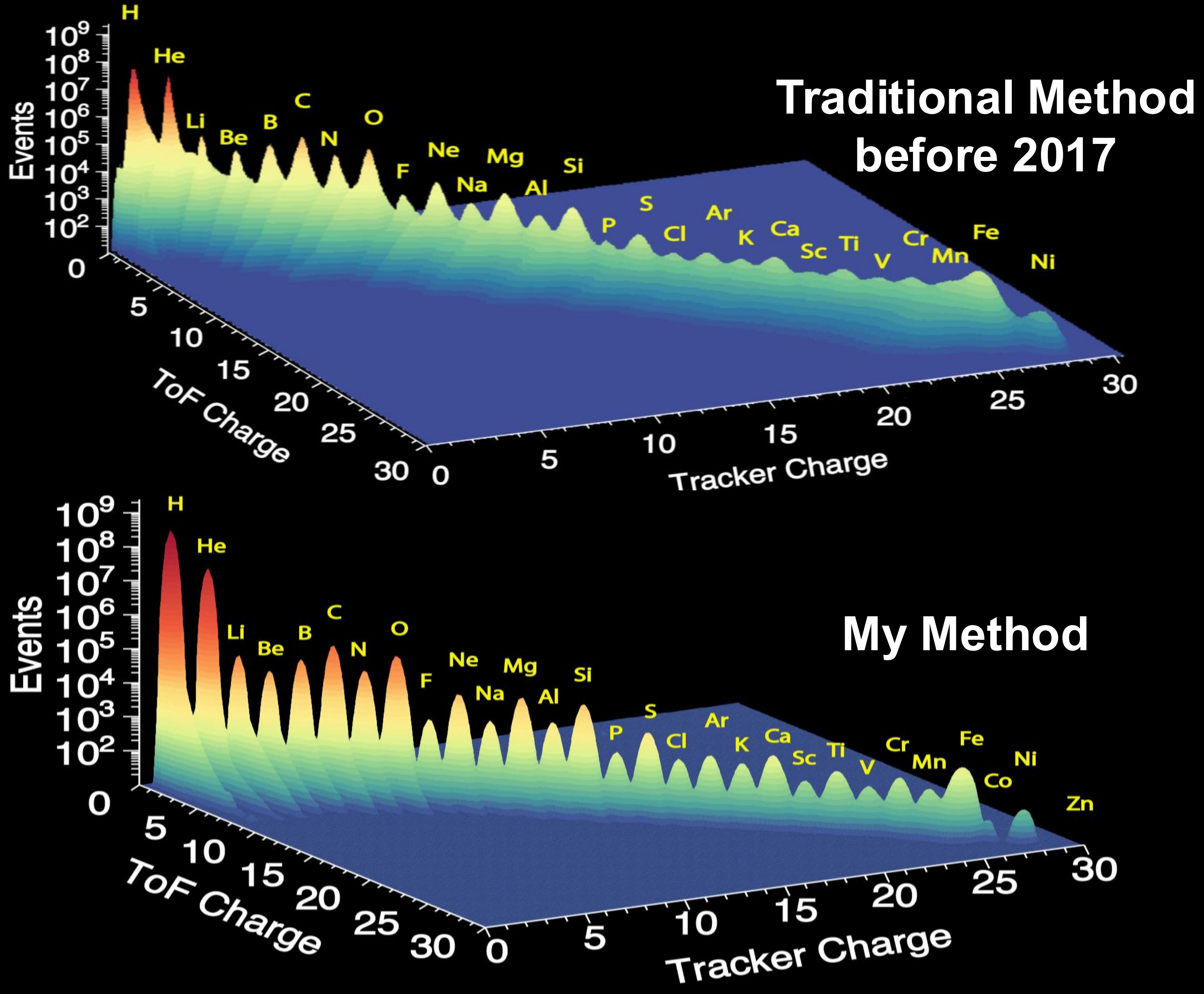


Improvement in the charge resolution

Improved by 200% and more

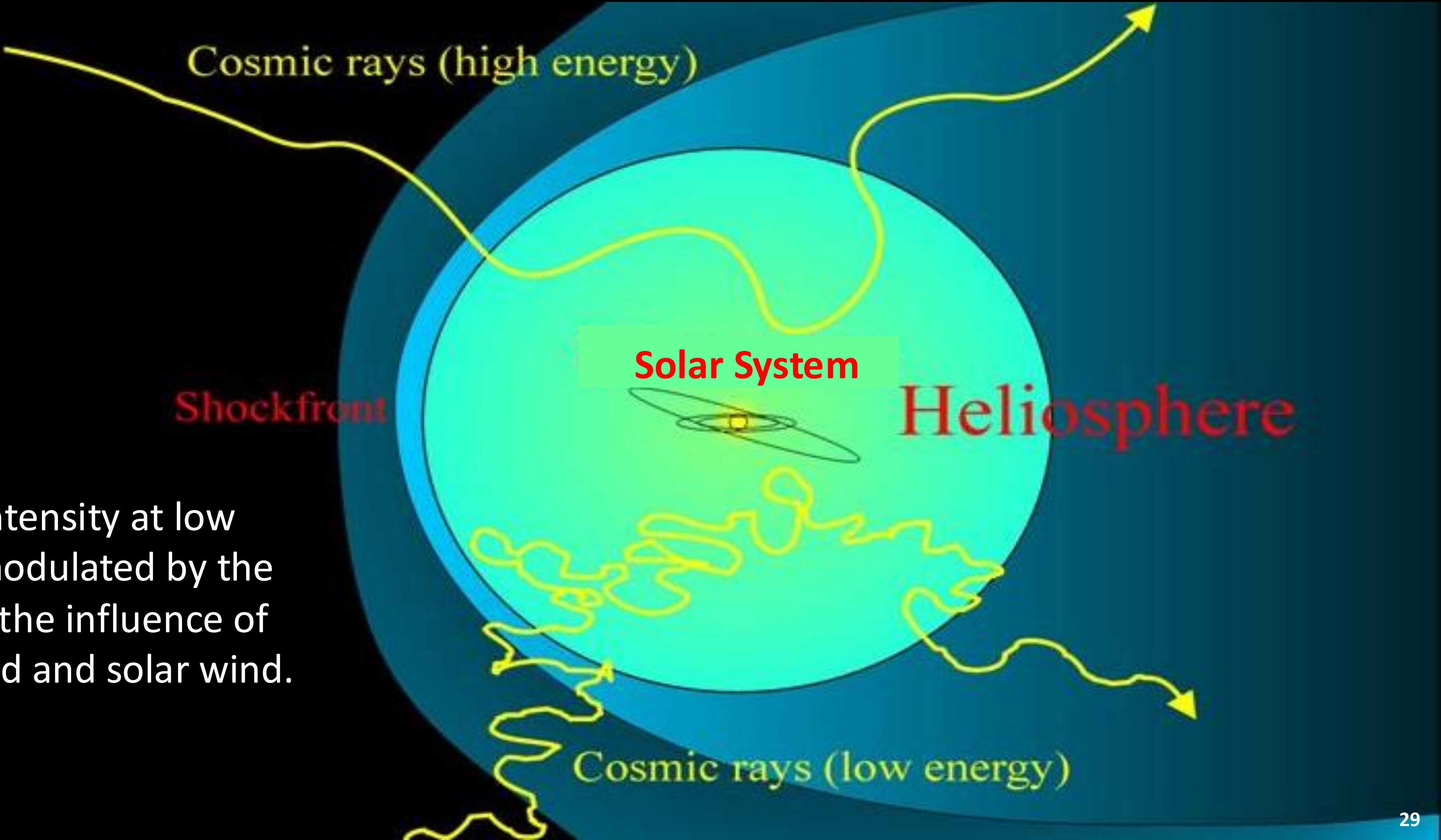


Charge Performance Comparison on AMS data



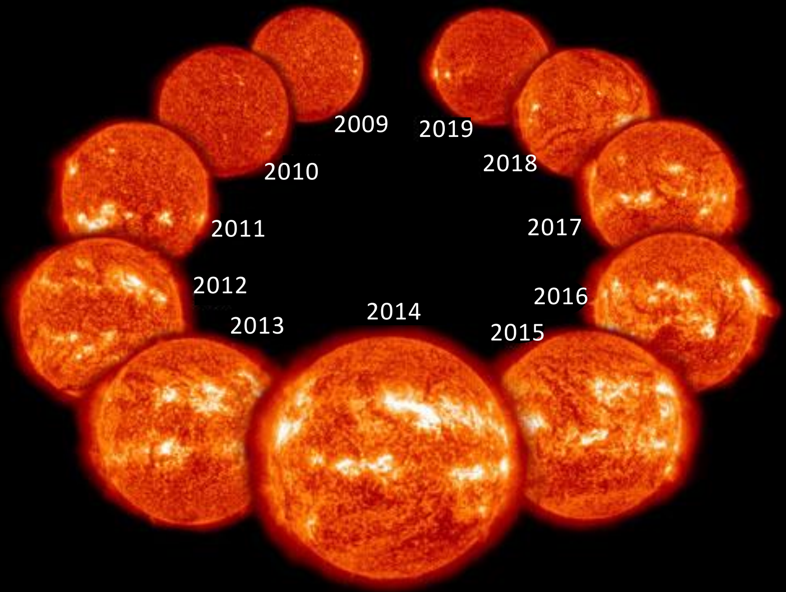
Past work: Solar Physics

Solar Modulation of Cosmic Rays



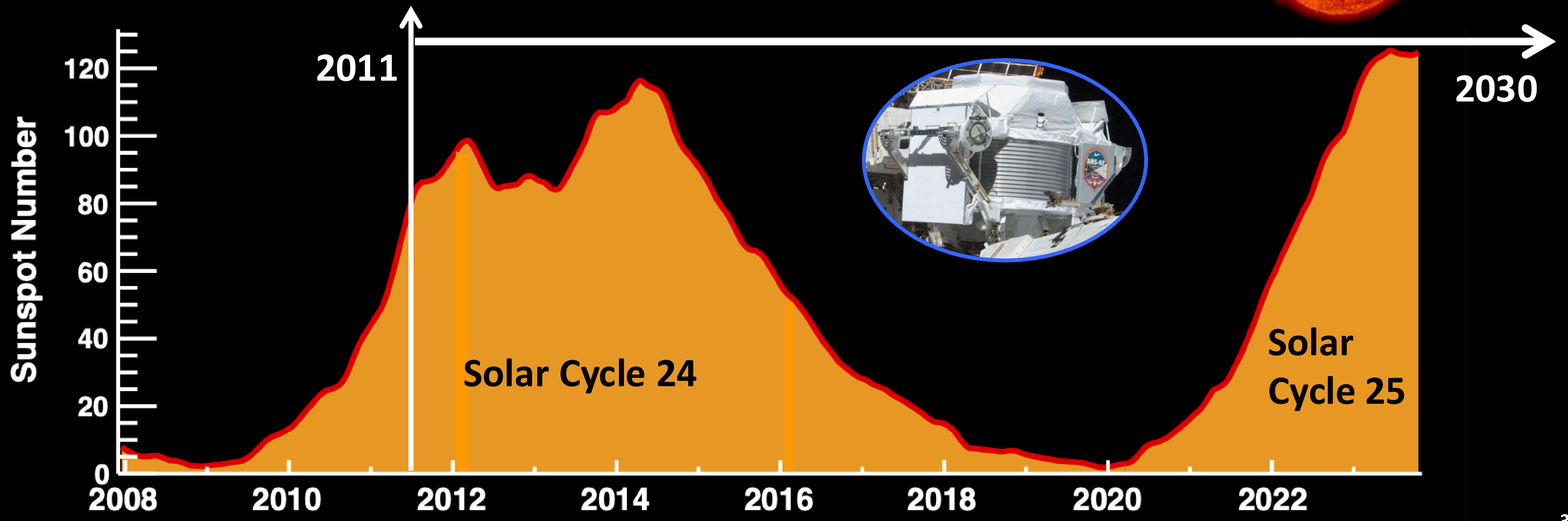
Cosmic ray intensity at low energies is modulated by the Sun through the influence of magnetic field and solar wind.

Long-term Scale Variation: Solar Cycle



The most significant long-term scale variation of cosmic rays is related to the 11-year solar cycle.

Sunspot activity is extensively recorded since 1755



Daily Flux Measurement

Isotropic flux in the i^{th} rigidity bin $(R_i, R_i + \triangle R_i)$ and j^{th} day

Number of selected events
(corrected for bin-to-bin migration)

$$\Phi_i^j = \frac{N_i^j}{A_i^j \, \epsilon_i^j \, T_i^j \, \triangle R_i}$$

Bin width

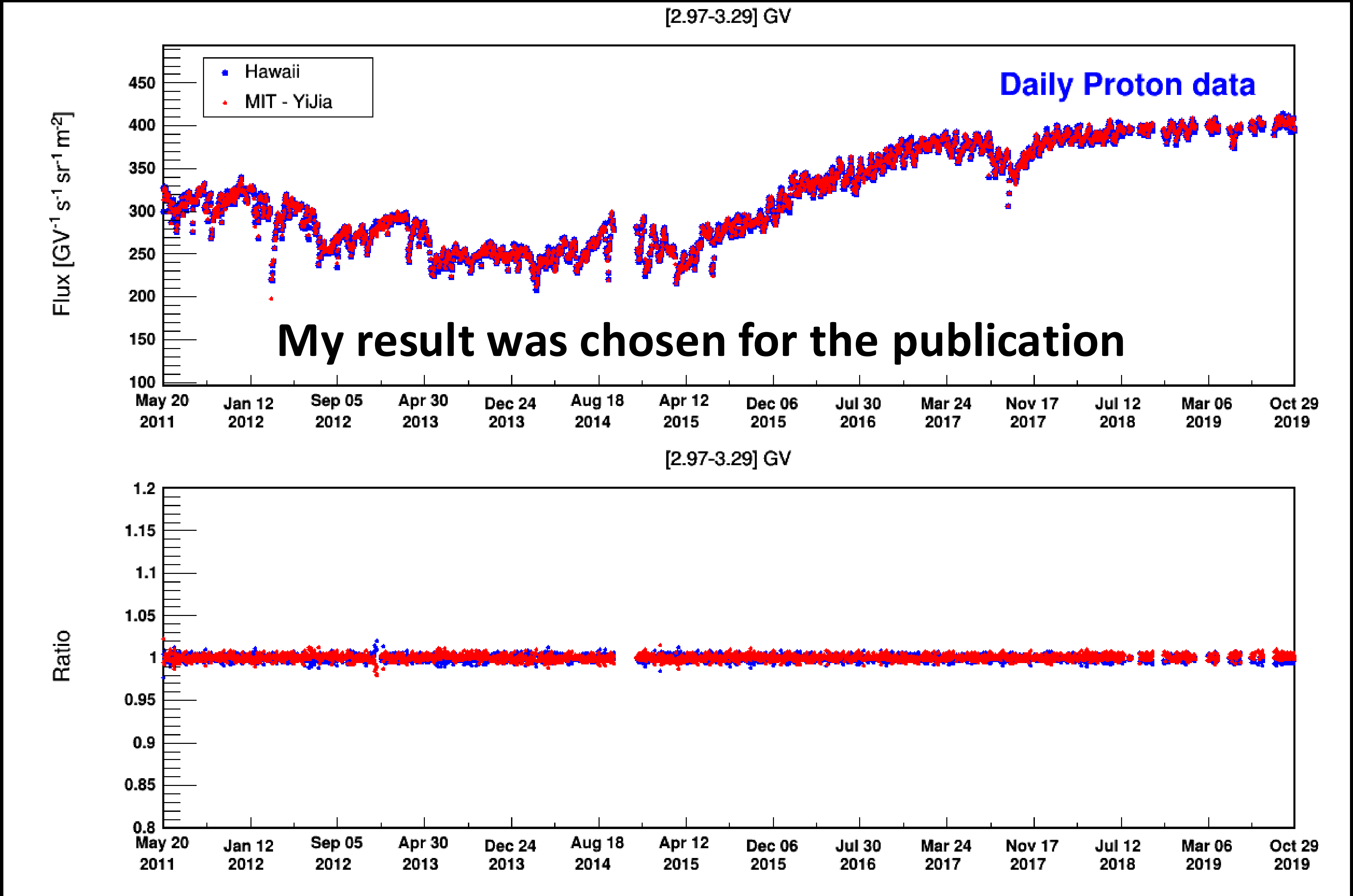
Effective acceptance
(from MC, verified with data)

Daily Trigger efficiency

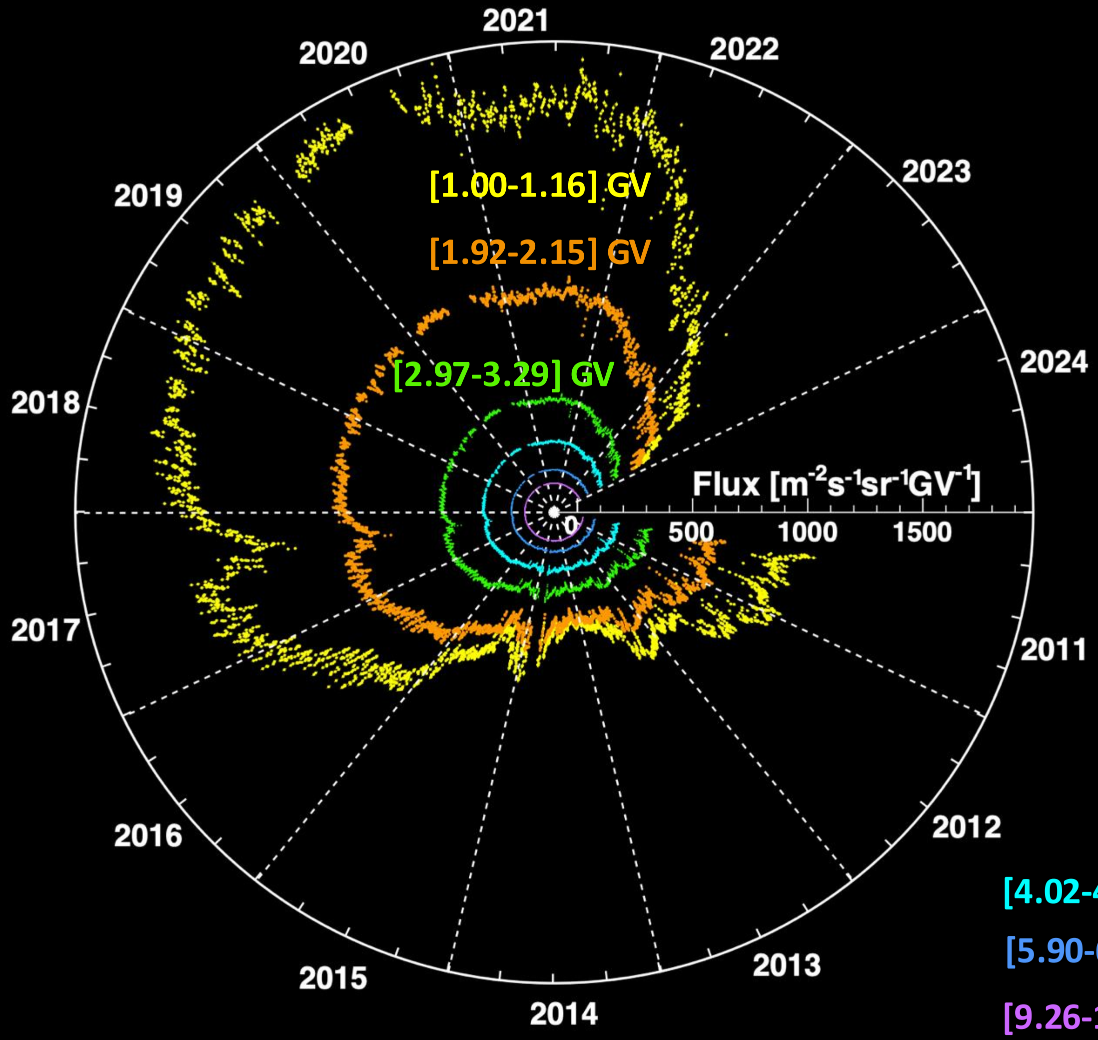
Daily collection time

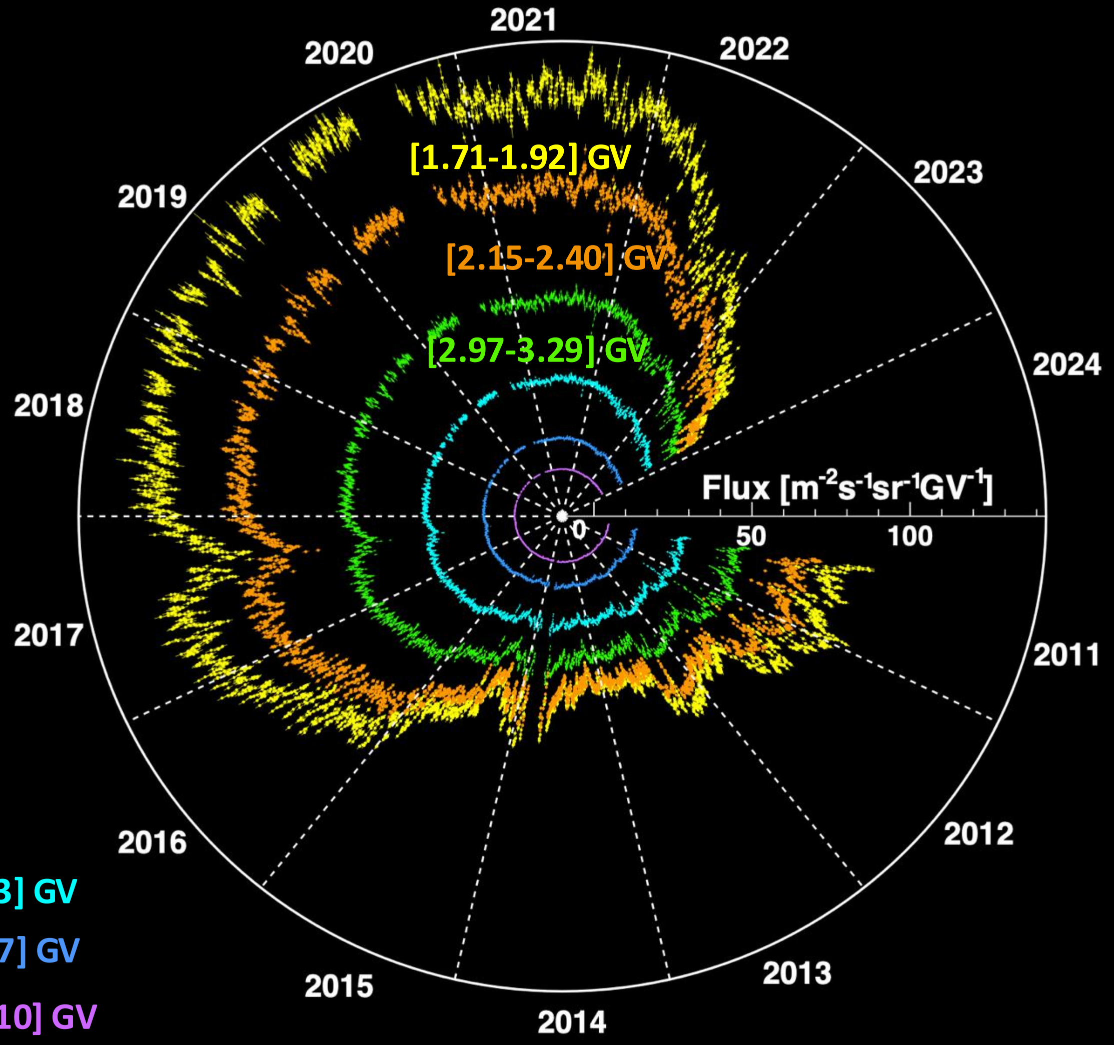
Extensive studies were made of the systematic errors for N_i^j, A_i^j, and ϵ_i^j.

Comparison of Proton Fluxes between Groups



AMS Daily Proton and Helium Fluxes



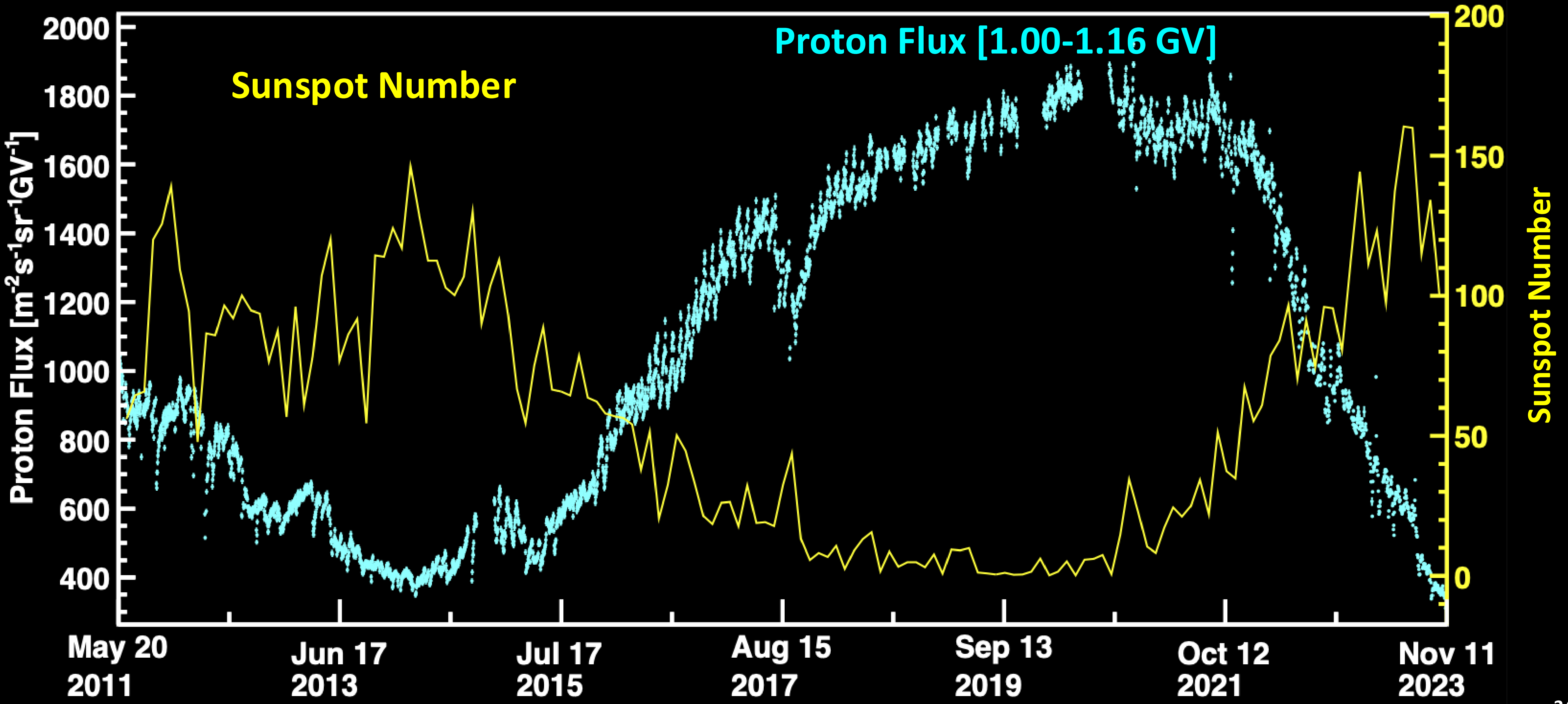


[4.02-4.43] GV
[5.90-6.47] GV
[9.26-10.10] GV

Most precise data available for the most abundant cosmic ray: Protons and Helium nuclei.
Long time span (>one Solar Cycle) and wide energy range (1-100 GV)

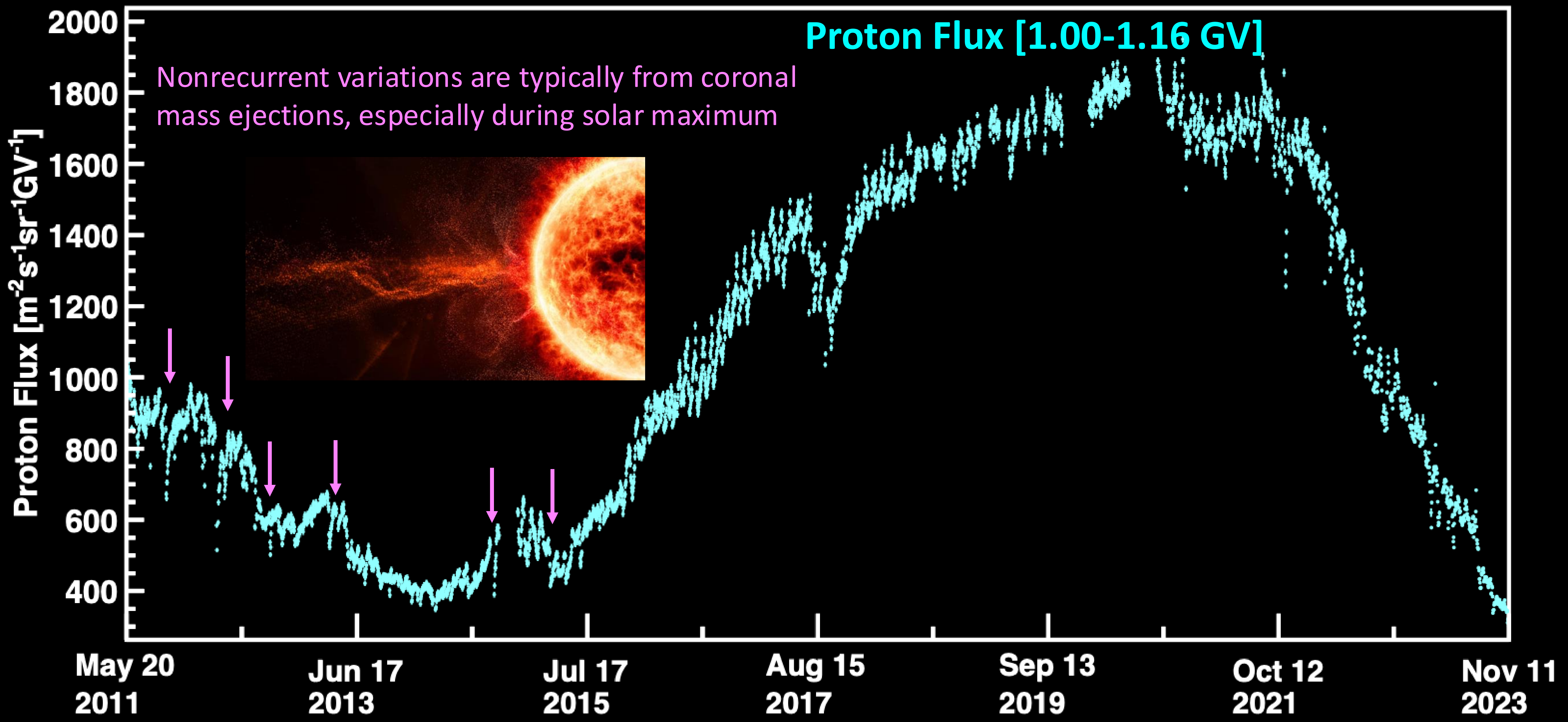
AMS Daily Proton Flux

Long Scale Variations are related to the 11-year Solar Cycle.



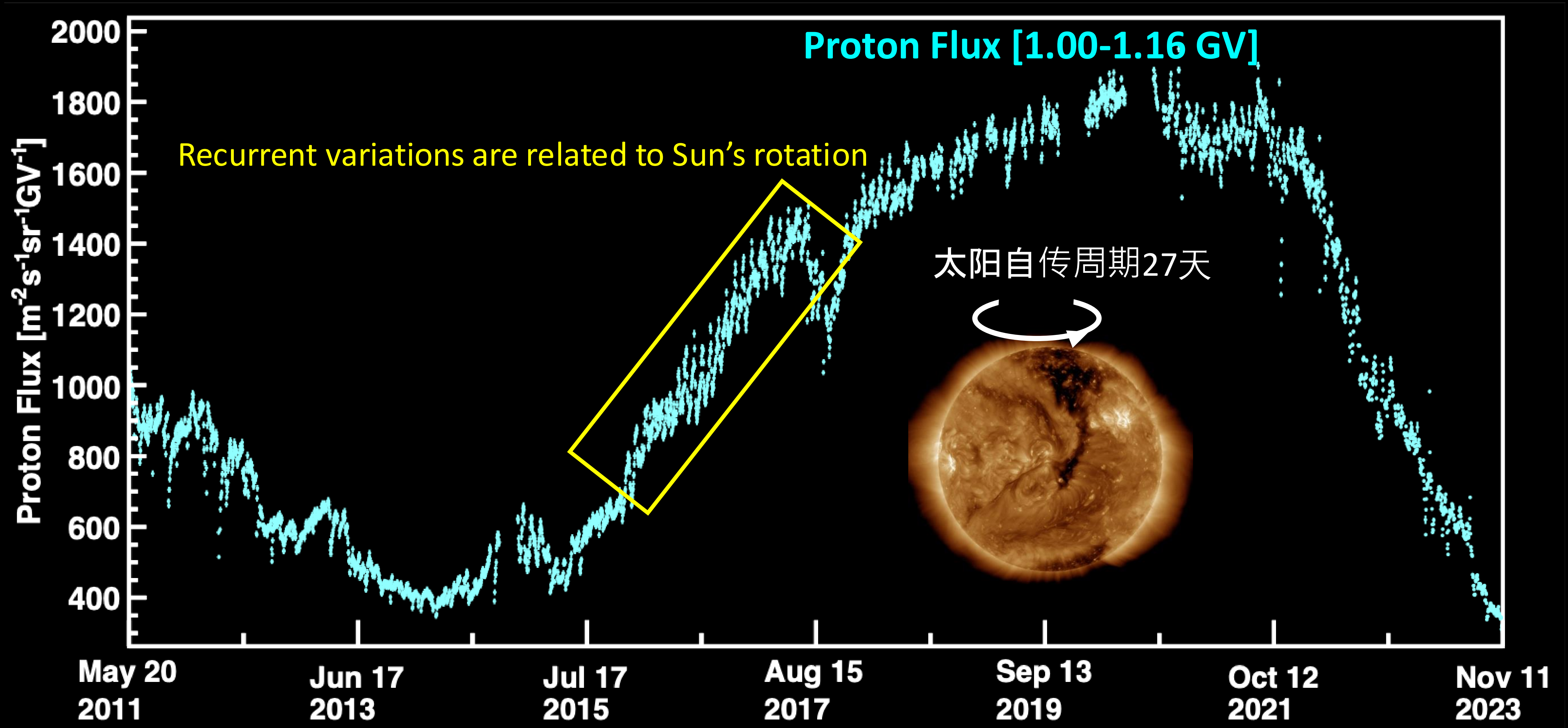
AMS Daily Proton Flux

Short scale variations can be either **nonrecurrent** or recurrent.

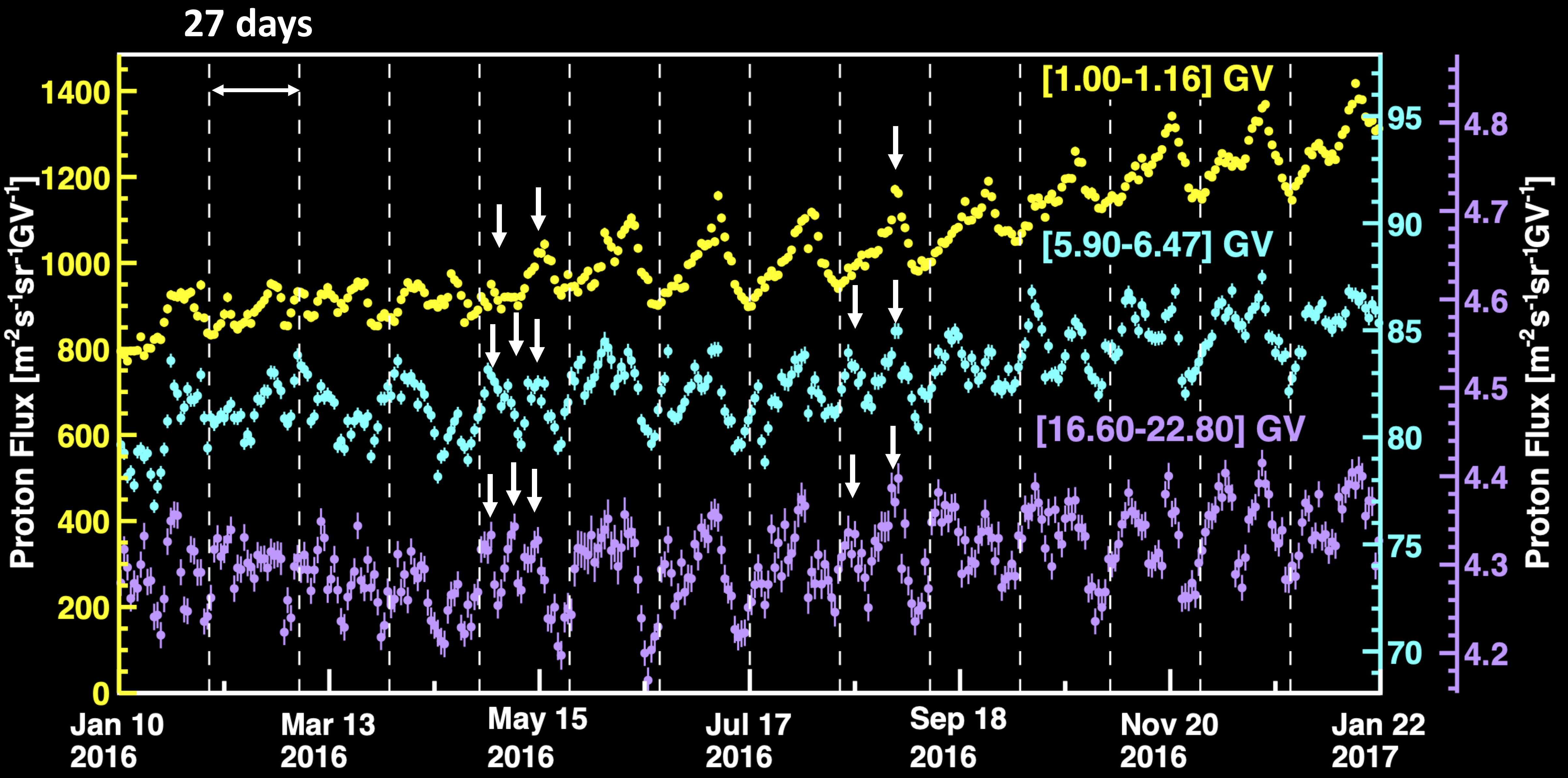


AMS Daily Proton Flux

Short scale variations can be either **nonrecurrent** or recurrent.

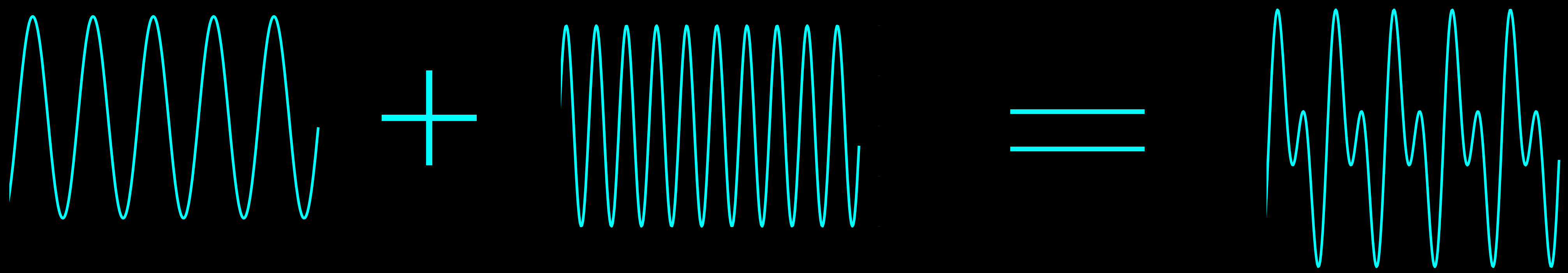


Recurrent Flux Variation with Periods of 9, 13.5, and 27 days in 2016



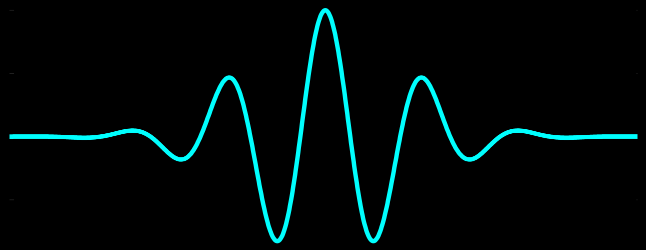
Frequency Analysis of Daily Fluxes

Fourier Transform represents data as a function of sinusoidal waves:



Drawback: sinusoids extend to infinity: not localized in time.

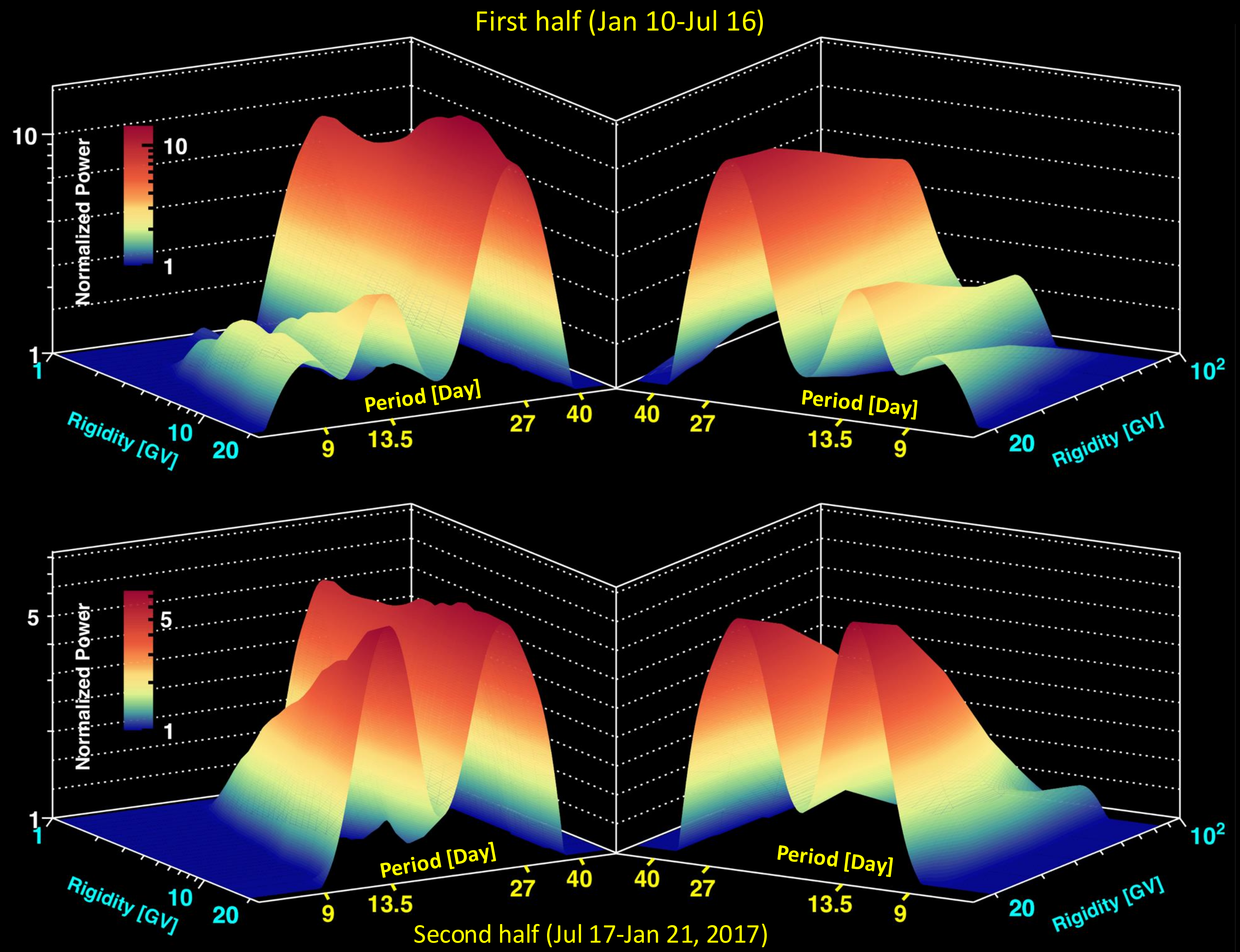
Wavelet: exist for finite duration: localized both in time and frequency space:



This method was first introduced by me for the analysis of proton data, and it has been widely adopted by the collaboration for the analysis of other particles (e^-,e^{+}…).

C. Torrence and G. P. Compo, Bull. Am. Meteorol. Soc. 79, 61 (1998)

Periodicities of Daily Proton Fluxes in 2016



Unexpectedly, the strength of **9-day and 13.5-day periodicities** increases with increasing rigidity up to **~10 GV** and **~20 GV,** respectively. Then the strength decreases with increasing rigidity up to **100 GV.**

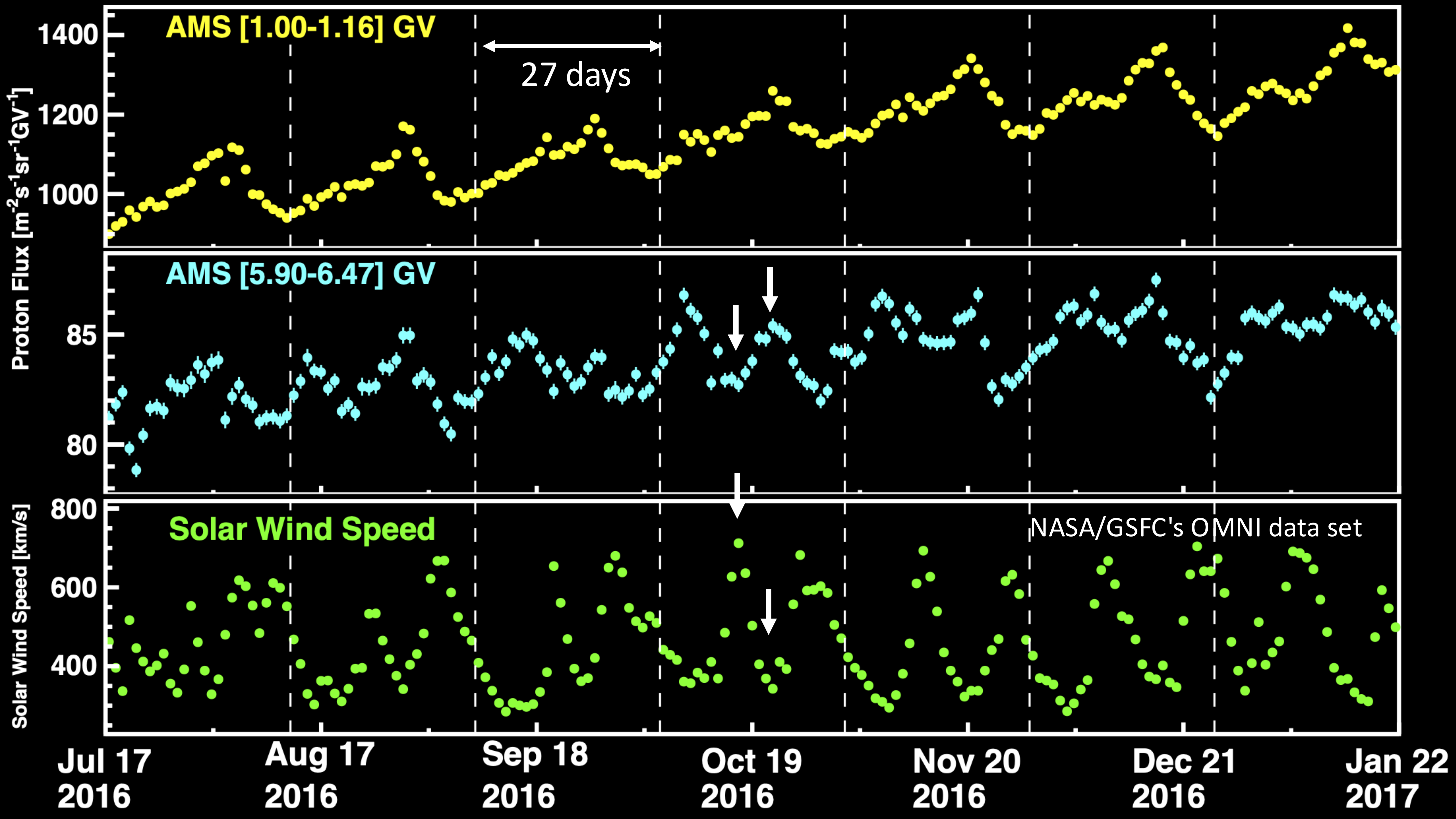
Thus, the AMS results do not support the general conclusion that the strength of the periodicities always decreases with increasing rigidity

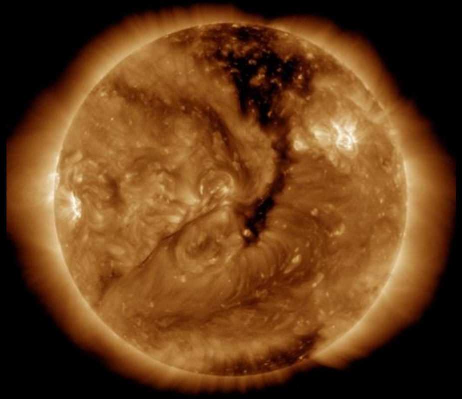
Phys. Rev. Lett. 127, 271102 (2021)

Main author

Example of Relation between the AMS Daily Flux and Solar Environment Parameter:

13.5-day period is observed in both cosmic ray and solar wind speed.

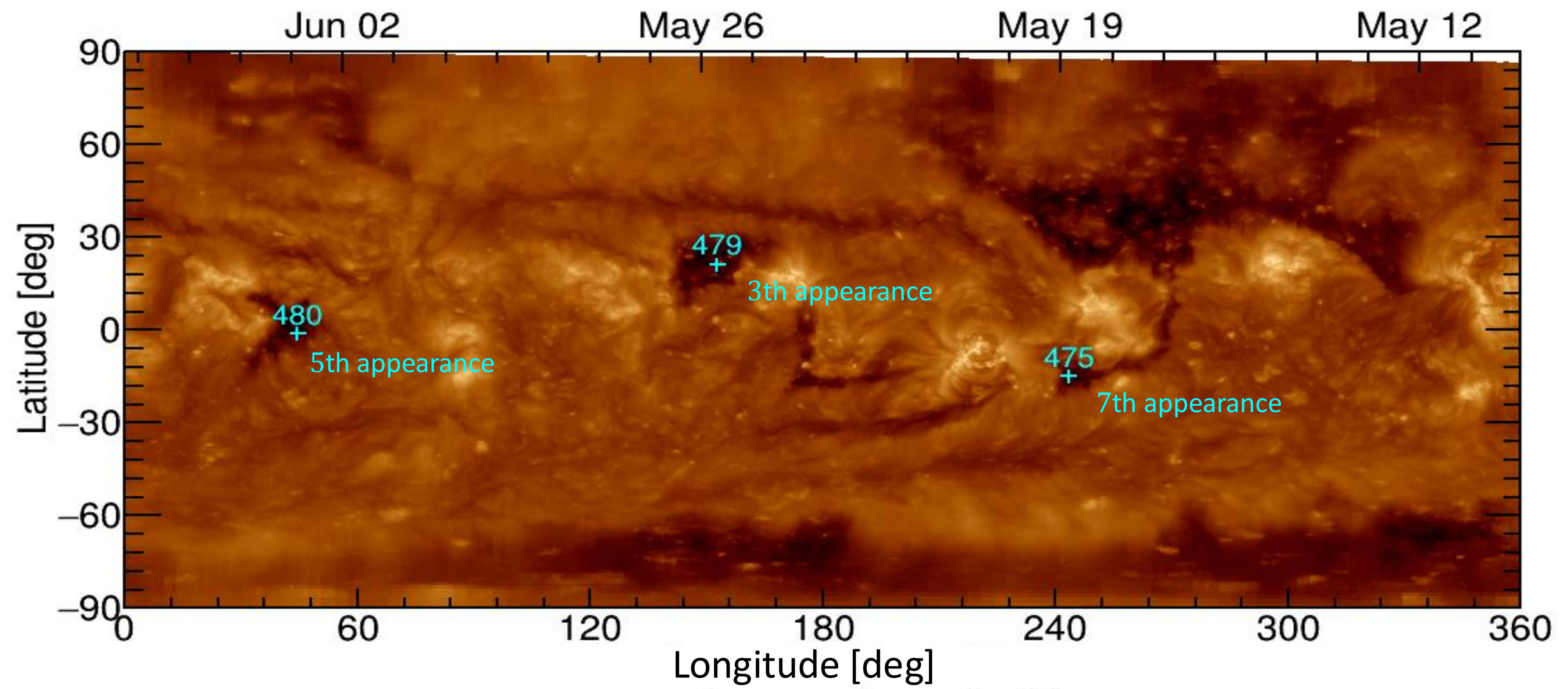




Connection to the Activities on the Surface of the Sun

Coronal Hole are sources of high speed solar wind affecting Earth. The rotation of the Sun causes multiple periods in the flux:

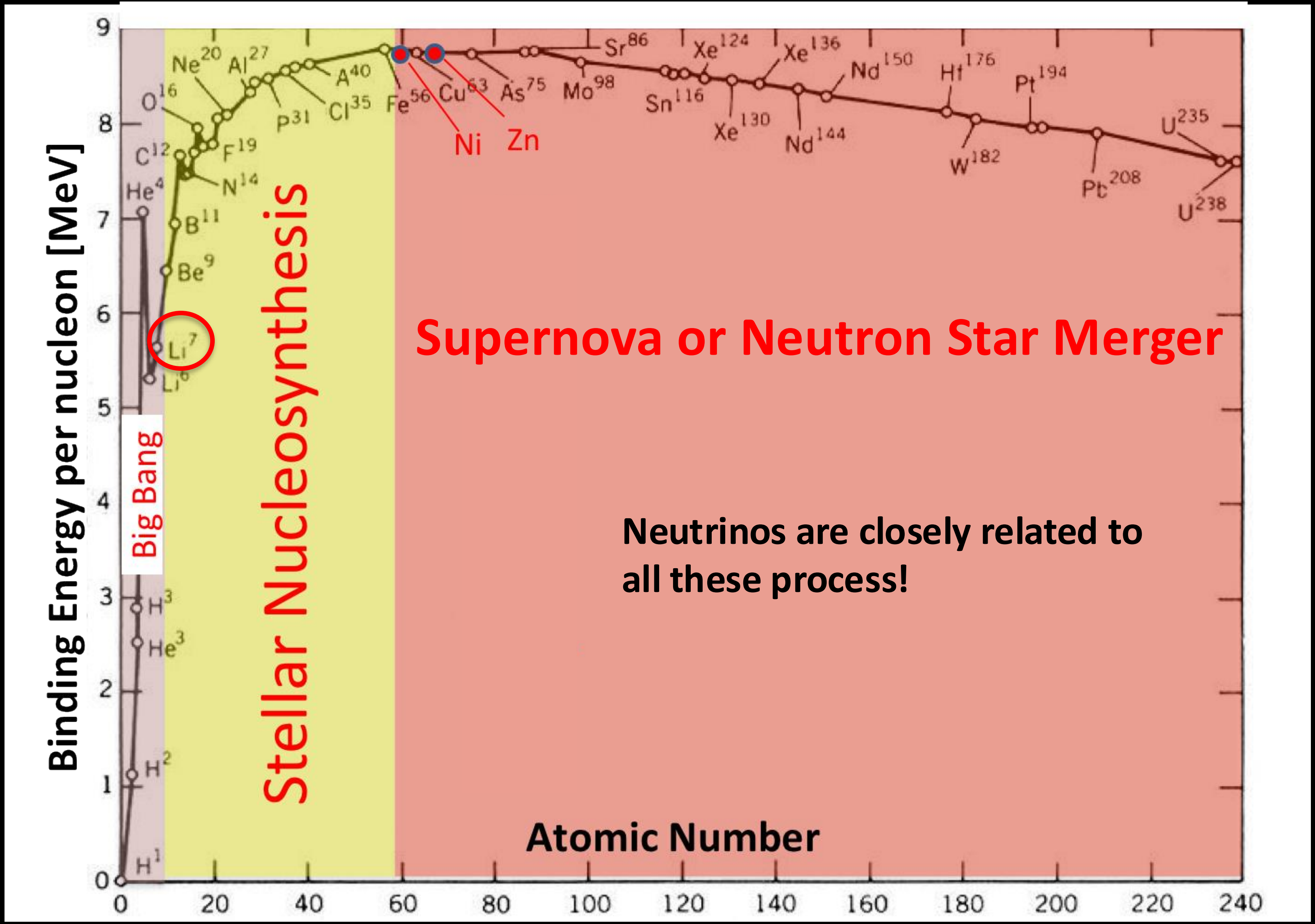
0 coronal hole:	⟶	No apparent periods
1 coronal hole	⟶	27-day period (a Bartels rotation)
2 coronal hole separated by 180°	⟶	13.5-day period
3 coronal holes separated by 120°	⟶	9-day period



(May 10, 2016-Jun 06, 2016) Image taken by Solar Dynamics Observatory (SDO), NASA

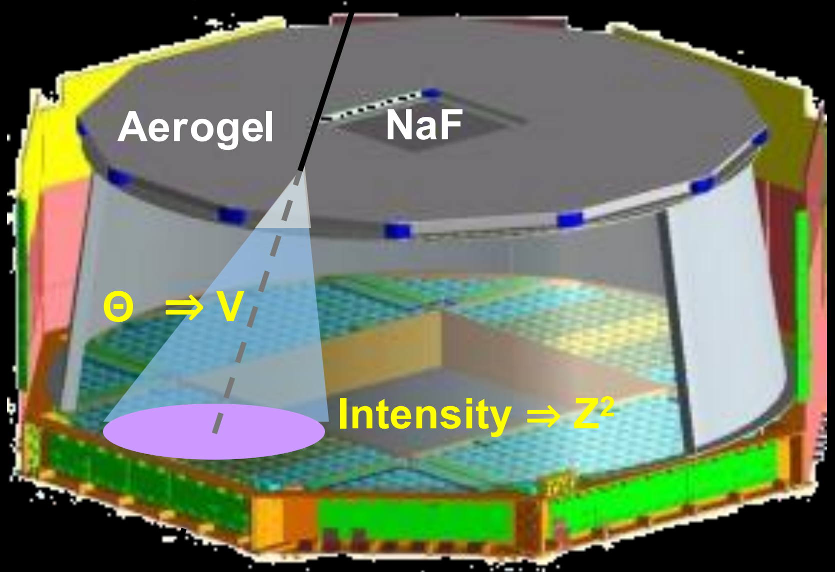
More recent work before I left AMS:
Li Isotopes

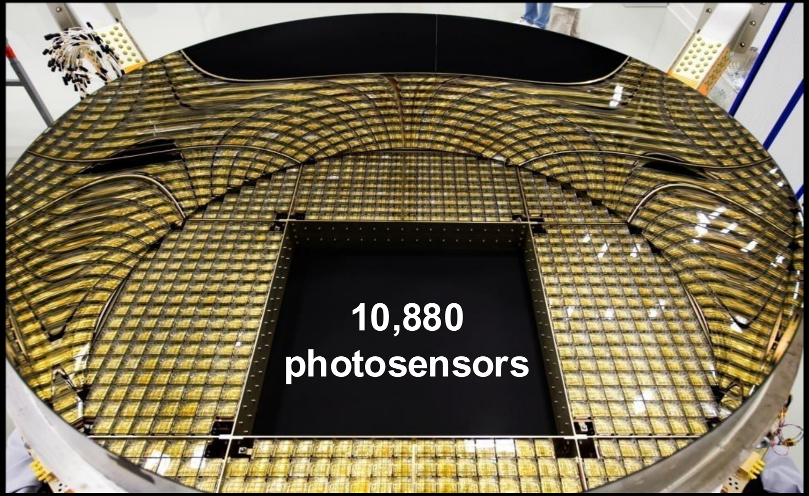
Origin of elements



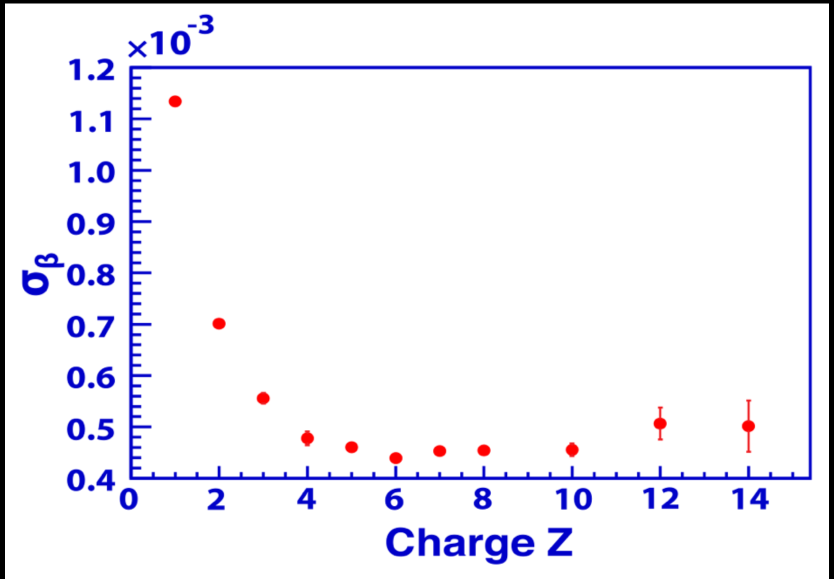
Lithium-7 Problem: The abundance of ^{7}Li predicted by the Big Bang nucleosynthesis is 4 times higher than what is observed in old, metal-poor stars. **Is there any primary ^{7}Li from big bang in cosmic ray?**

AMS环形成像切仑科夫探测器(RICH)

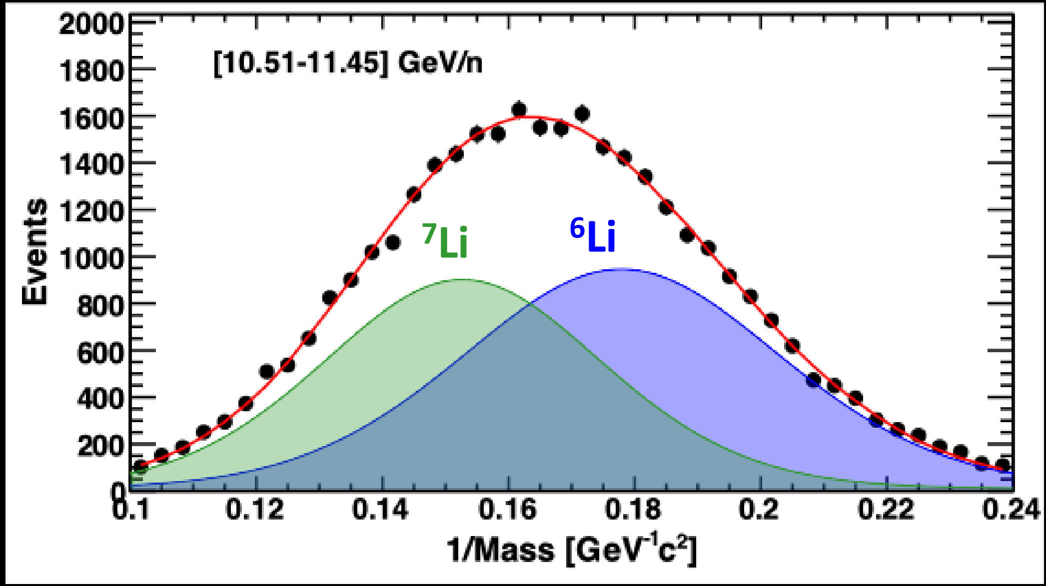




Velocity resolution

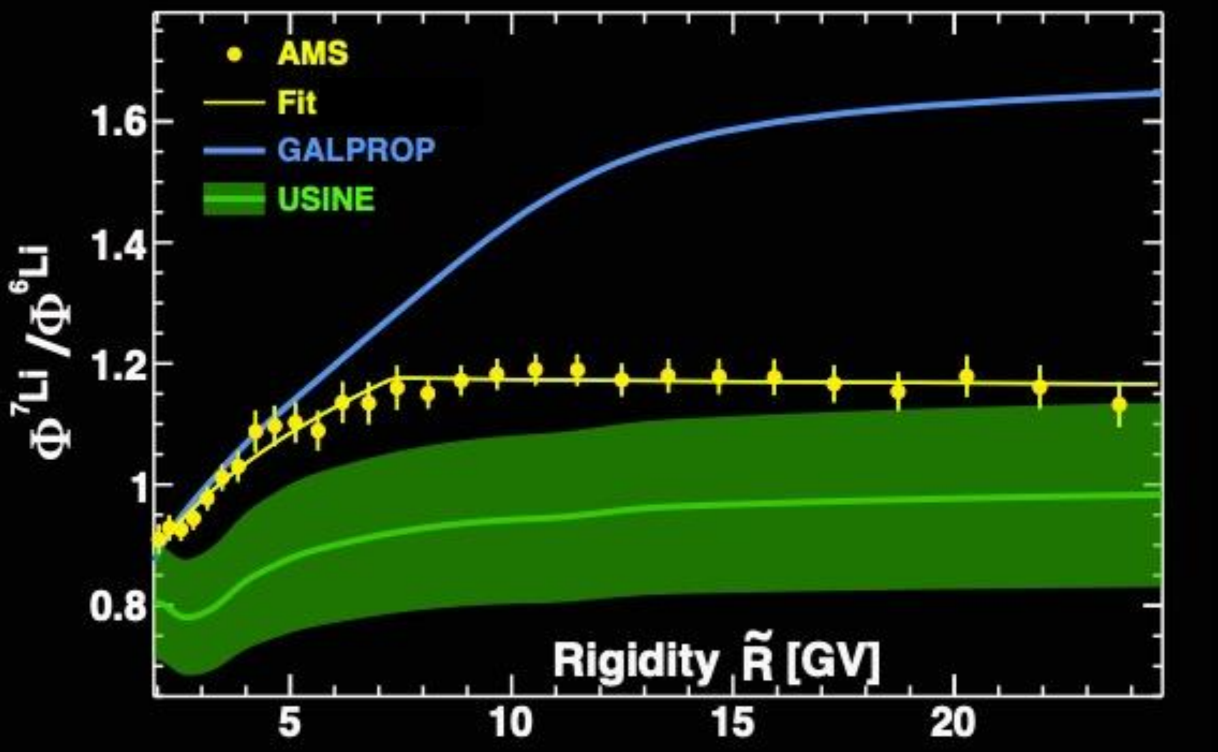


Particle mass is deduced by simultaneous measurement of velocity and momentum (Tracker with magnetic).

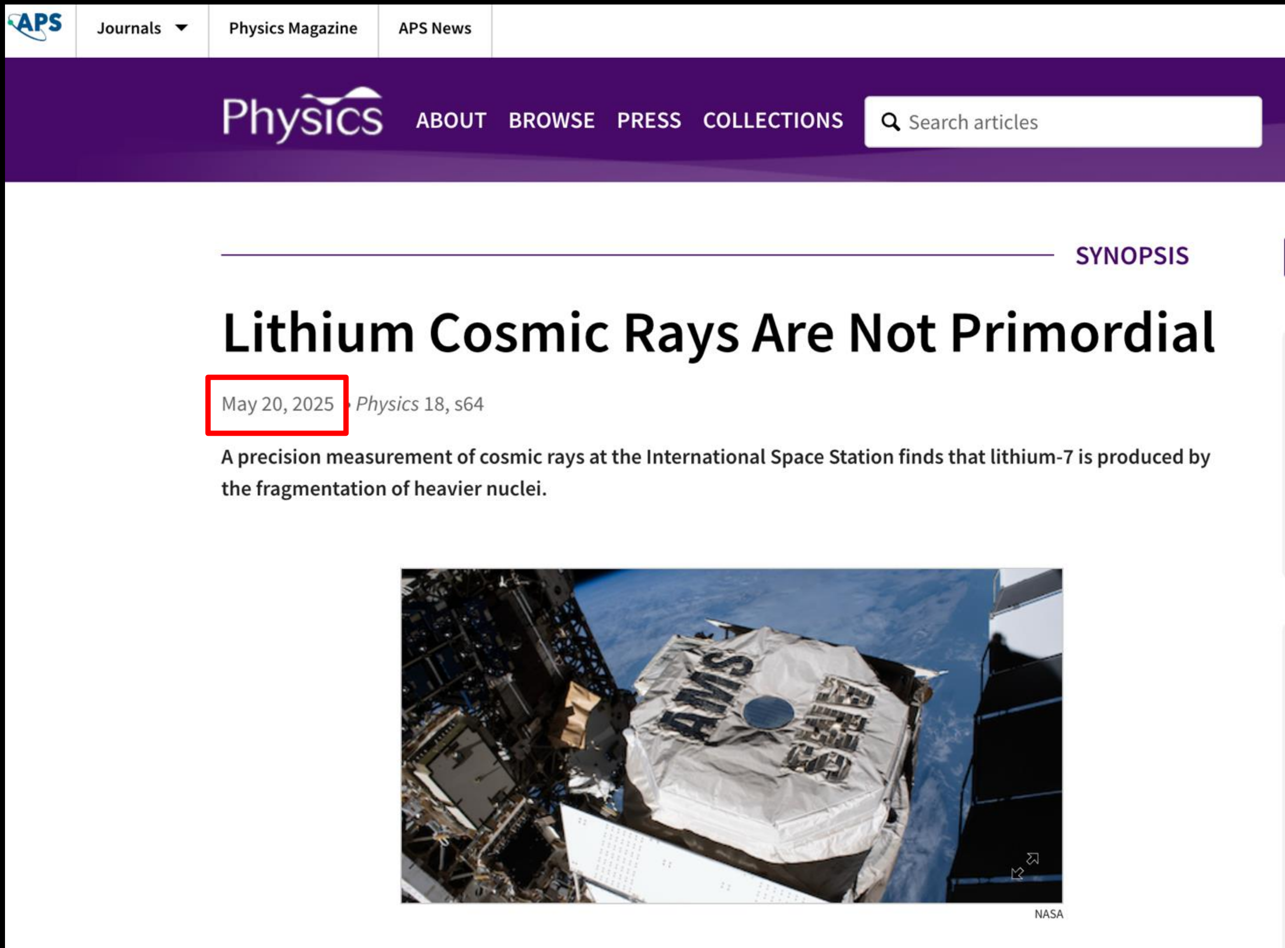


New AMS Observation

Above 7 GV, ^{6}Li and ^{7}Li fluxes have an identical rigidity dependence. This excludes the existence of a sizable primary component in the ^{7}Li flux.

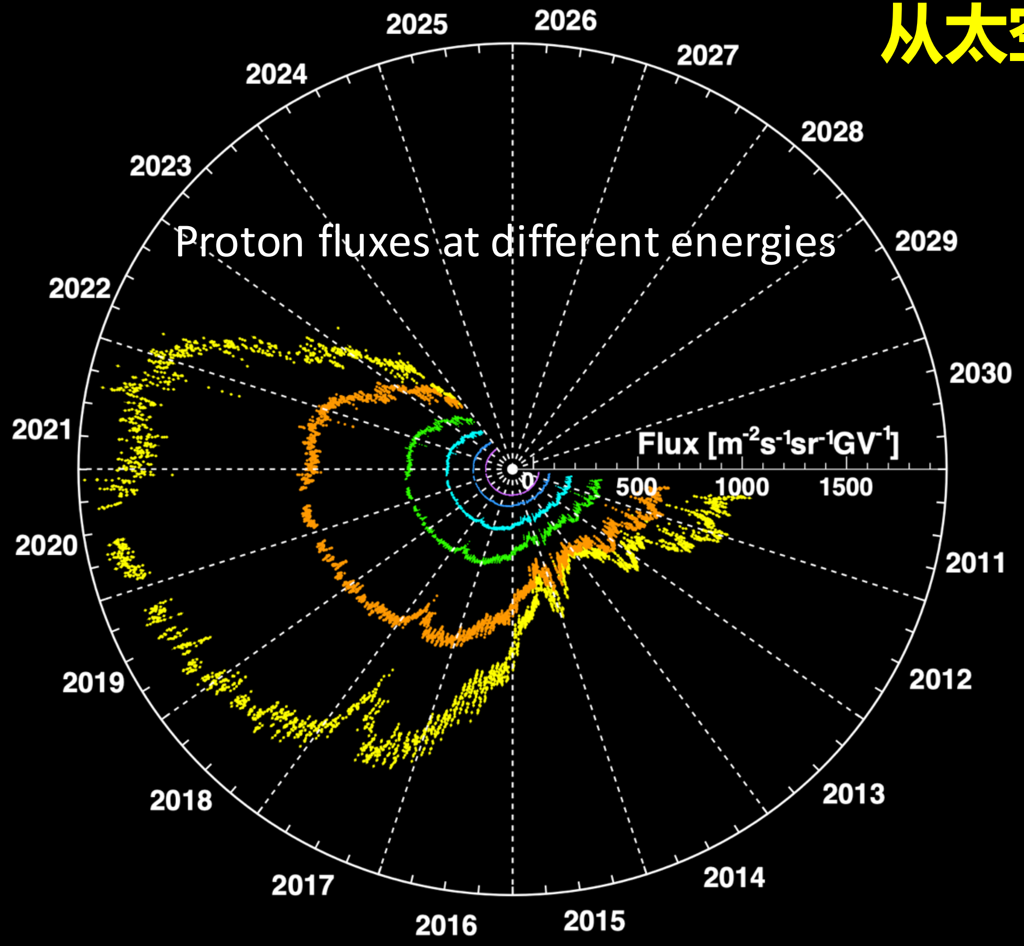


AMS data is challenging current models (GALPROP, USINE)

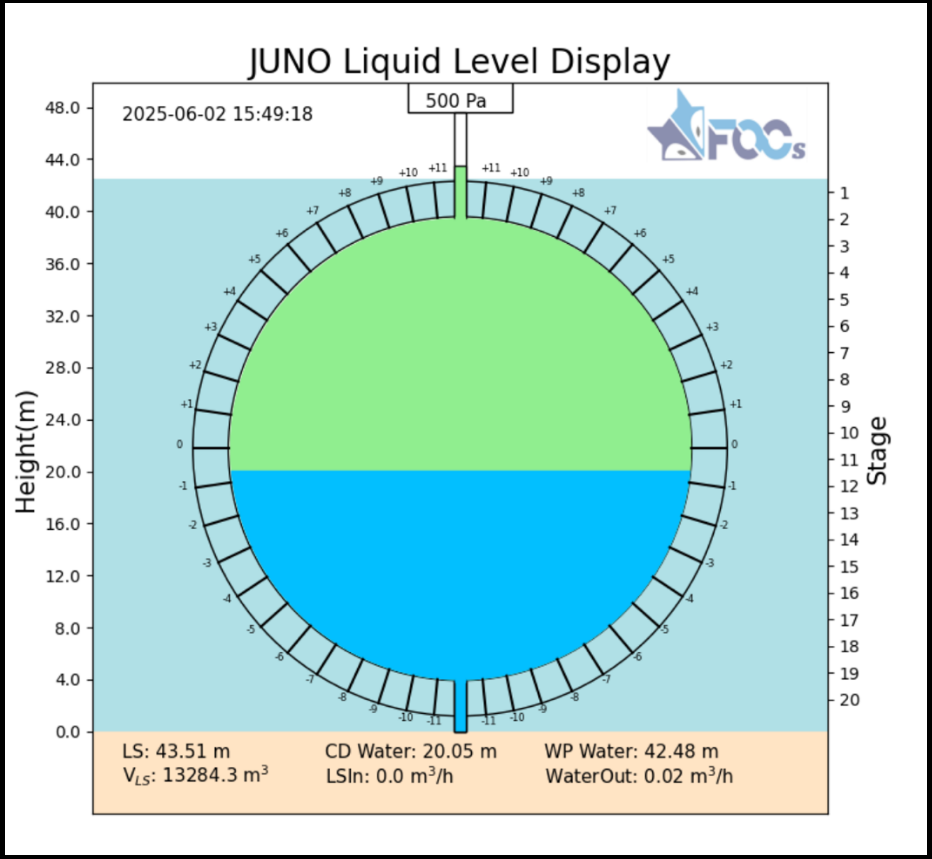


Main author

从太空到地下



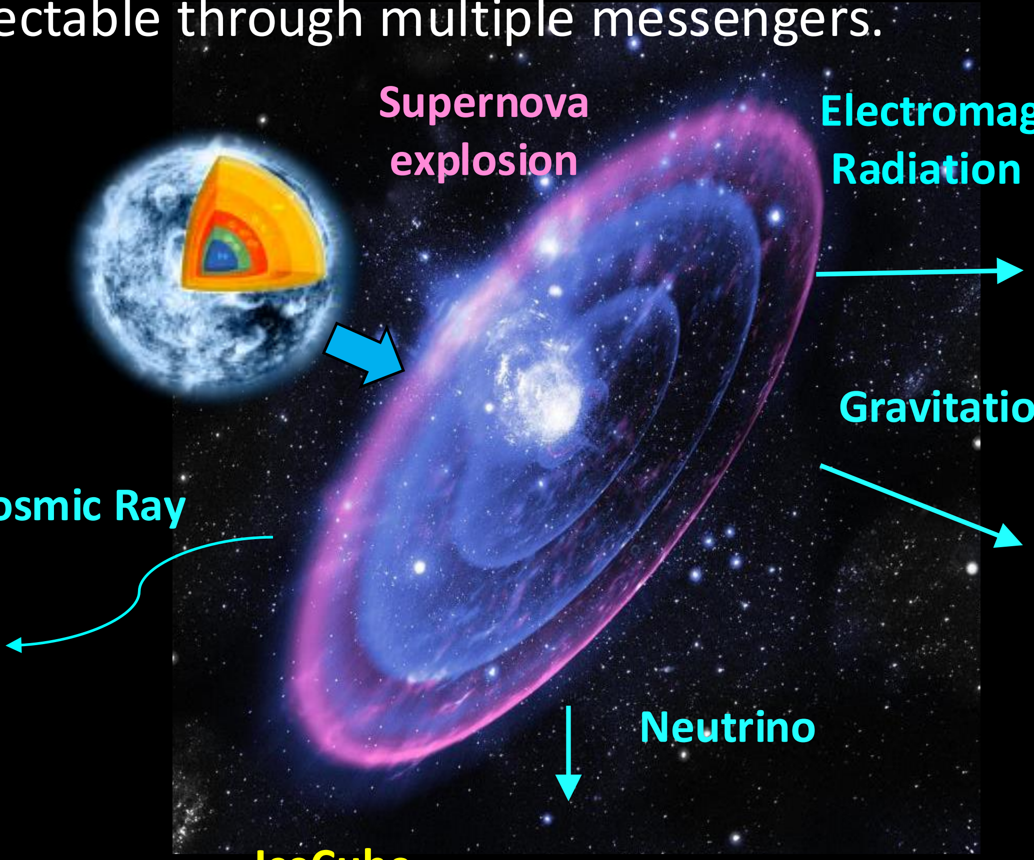
AMS has been running on the International Space Station for 14 years



JUNO is at its beginning of data-taking

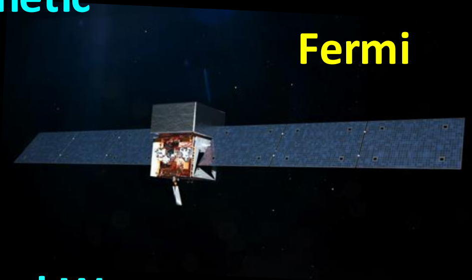
Study of Supernova in the Era of Multi-Messenger Astronomy

A **supernova** is the explosive death of a massive star, releasing enormous amounts of energy in various forms, detectable through multiple messengers.



Electromagnetic Radiation

Fermi



H.E.S.S.

...

Gravitational Wave

LIGO

Virgo

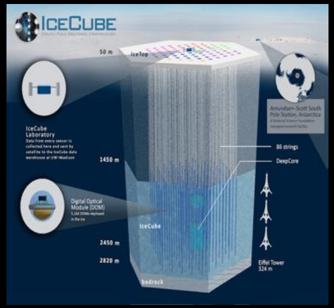
...

AMS

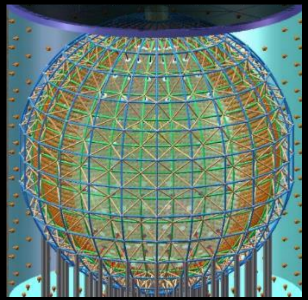
Pierre Auger

...

IceCube



JUNO



...

JUNO detector

Proposed in 2008 as a reactor neutrino experiment for mass ordering

→ driving the design specifications:

location, 20 kton Liquid Scintillator, 3% energy resolution, 700 m underground

Approved in 2013. Construction in 2015-2025.

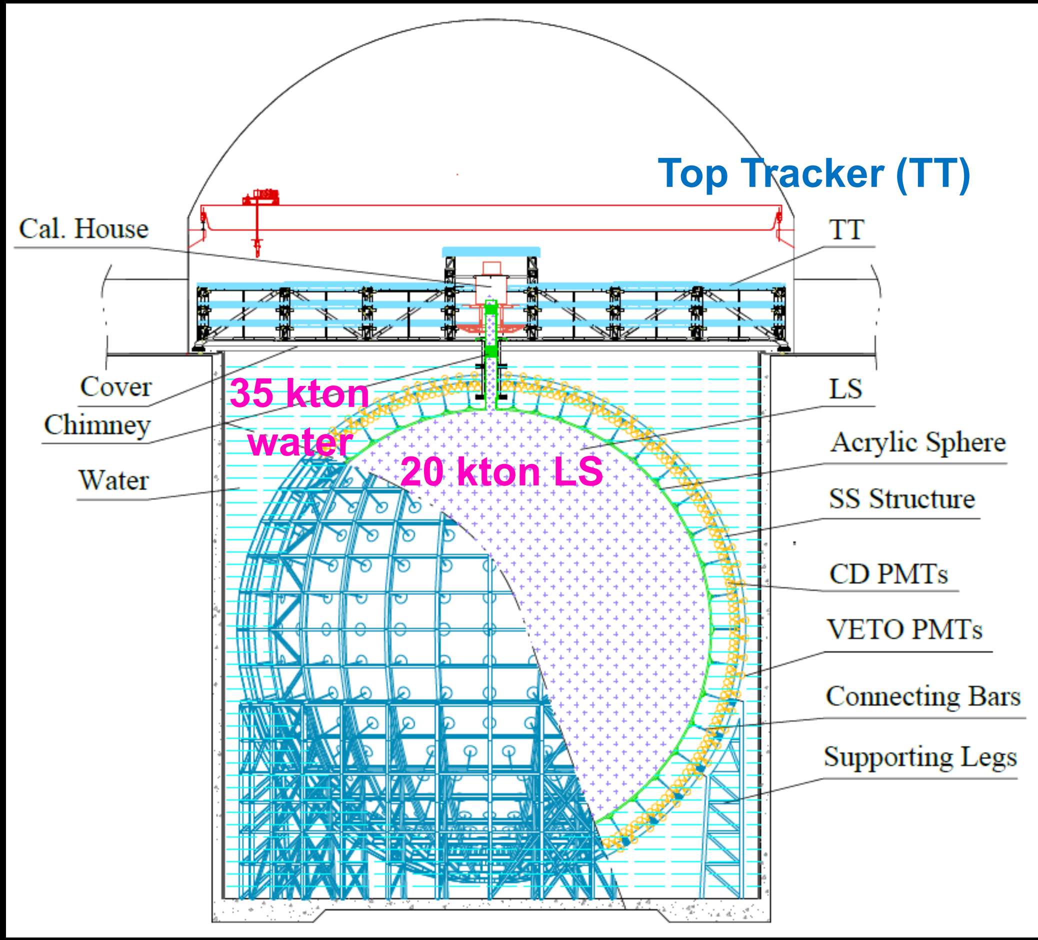
A multiple-purpose neutrino experiment with rich physics programs:

- Reactor neutrinos
- Atmospheric neutrinos
- Solar neutrinos
- Supernova burst neutrinos
- Supernova relic neutrinos
- Geoneutrinos
- Nucleon decay
- Dark Matter
- …

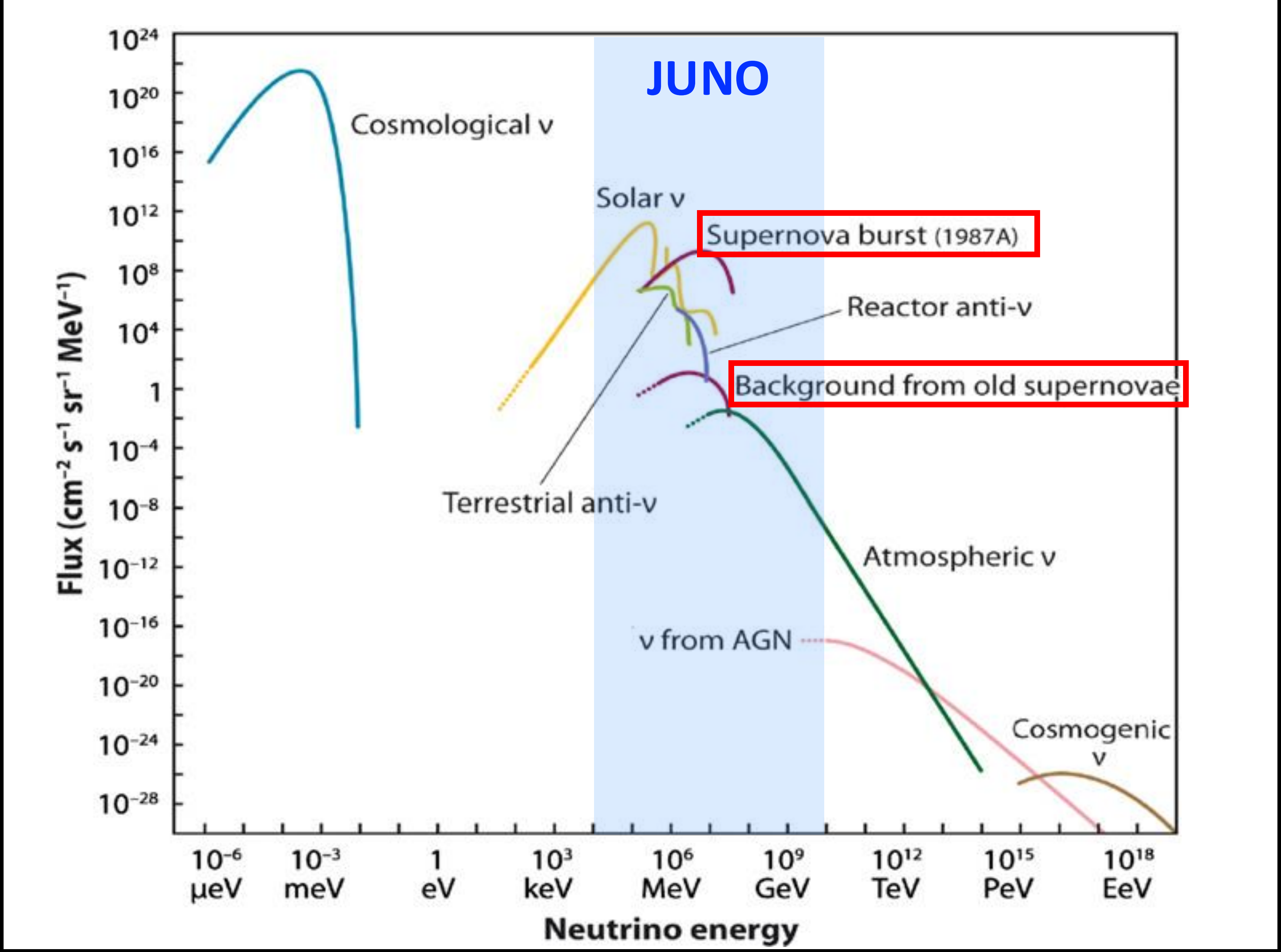
Acrylic Sphere:
Inner Diameter: 35.4 m
Thickness: 12 cm

Stainless Steel Structure:
Inner Diameter: 40.1 m
Outer Diameter: 41.1 m
17612 20-inch PMTs,
25600 3-inch PMTs

Water Pool:
Inner Diameter: 43.5 m
Height: 44 m
Depth: 43.5 m
2400 20-inch PMTs

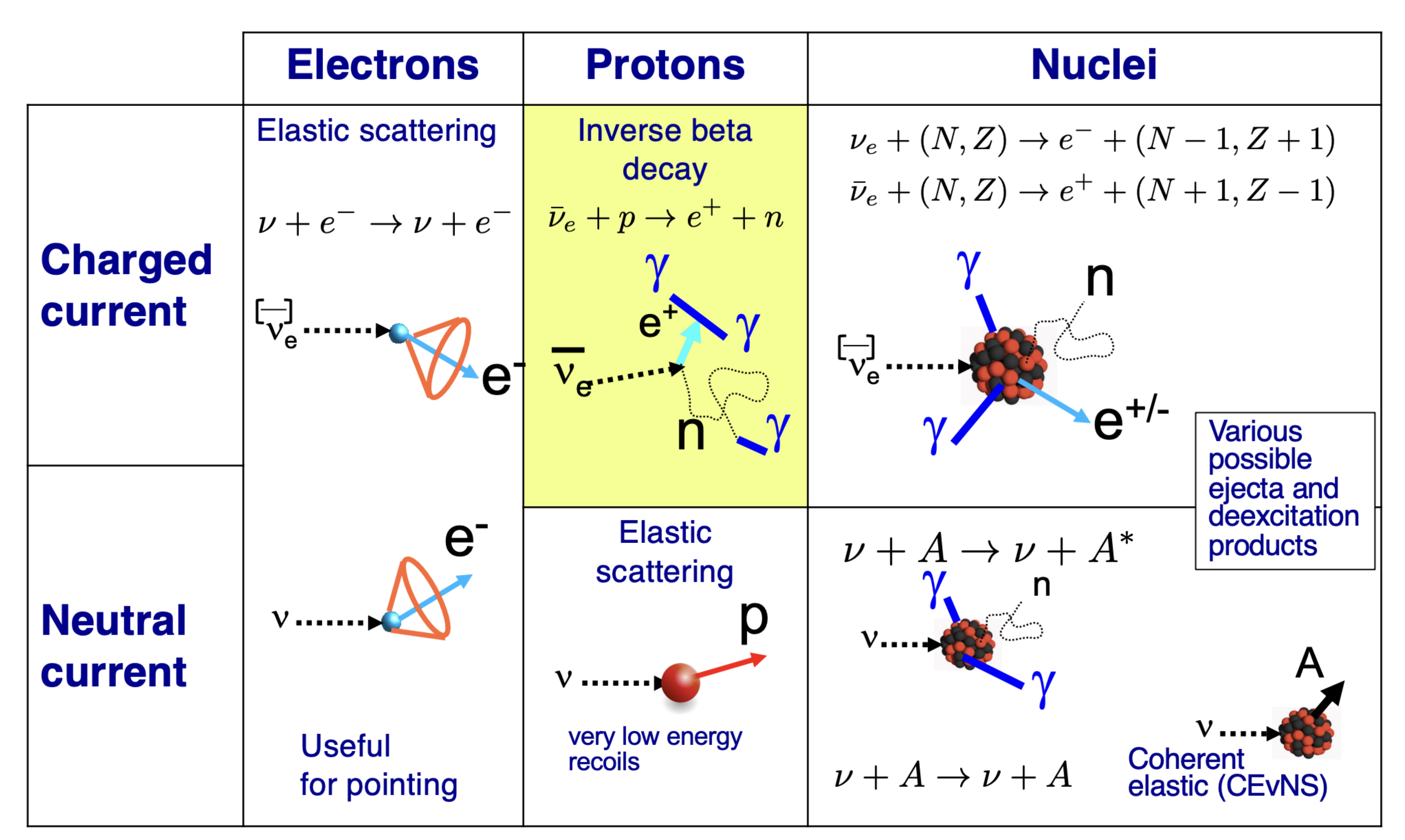


Neutrino Spectrum at Earth



U. Katz and C. Spiering, Prog. Part. Nucl. Phys. 67, 651 (2012)

Neutrino Interactions in the ~10 MeV range

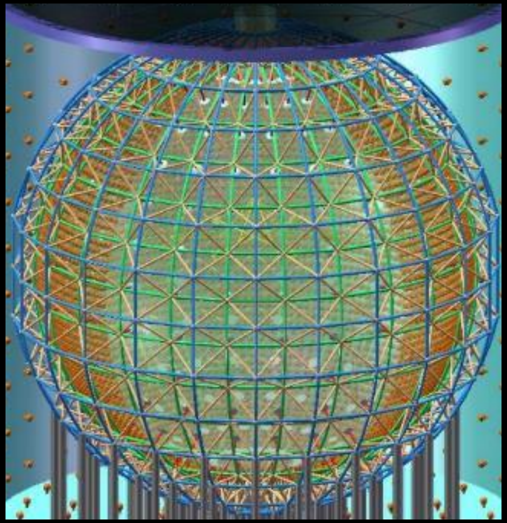


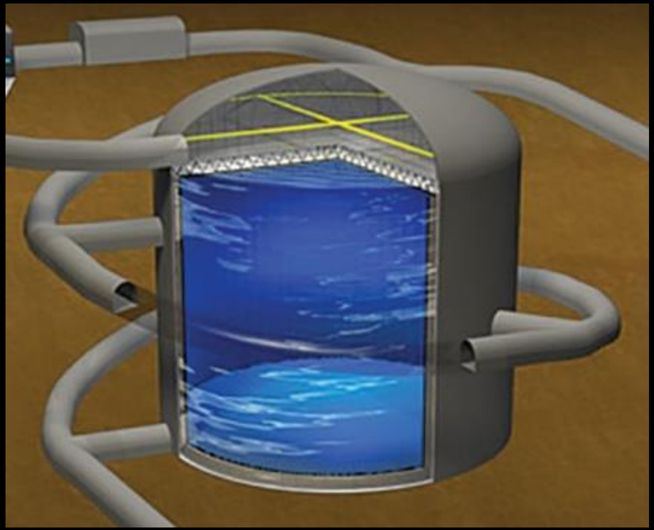
Future Large Supernova-Burst-Sensitive Neutrino Detectors

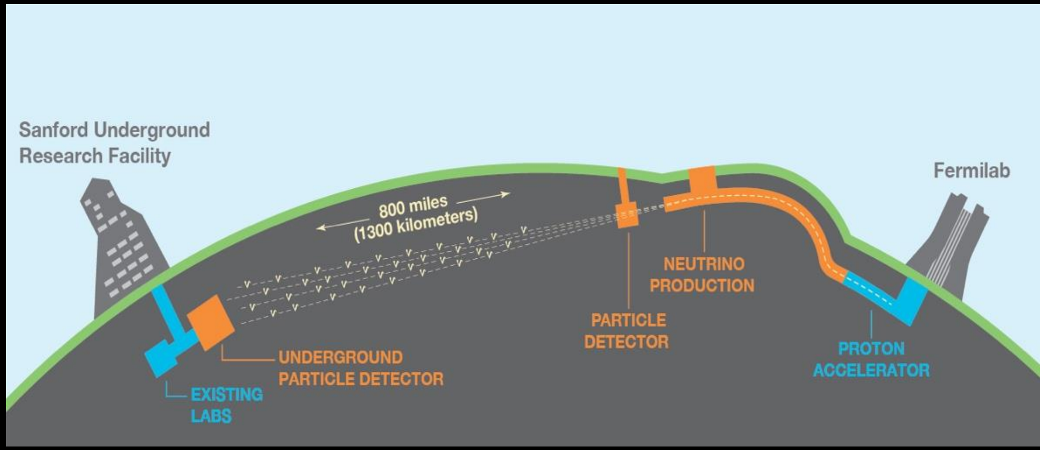
JUNO
20 kton Liquid Scintillator

Hyper-Kamiokande (Japan)
260 kton water

DUNE (USA)
40 kton liquid Argon







Operation Start: 2025 → 2028 → Late-2020s

Multiple channels

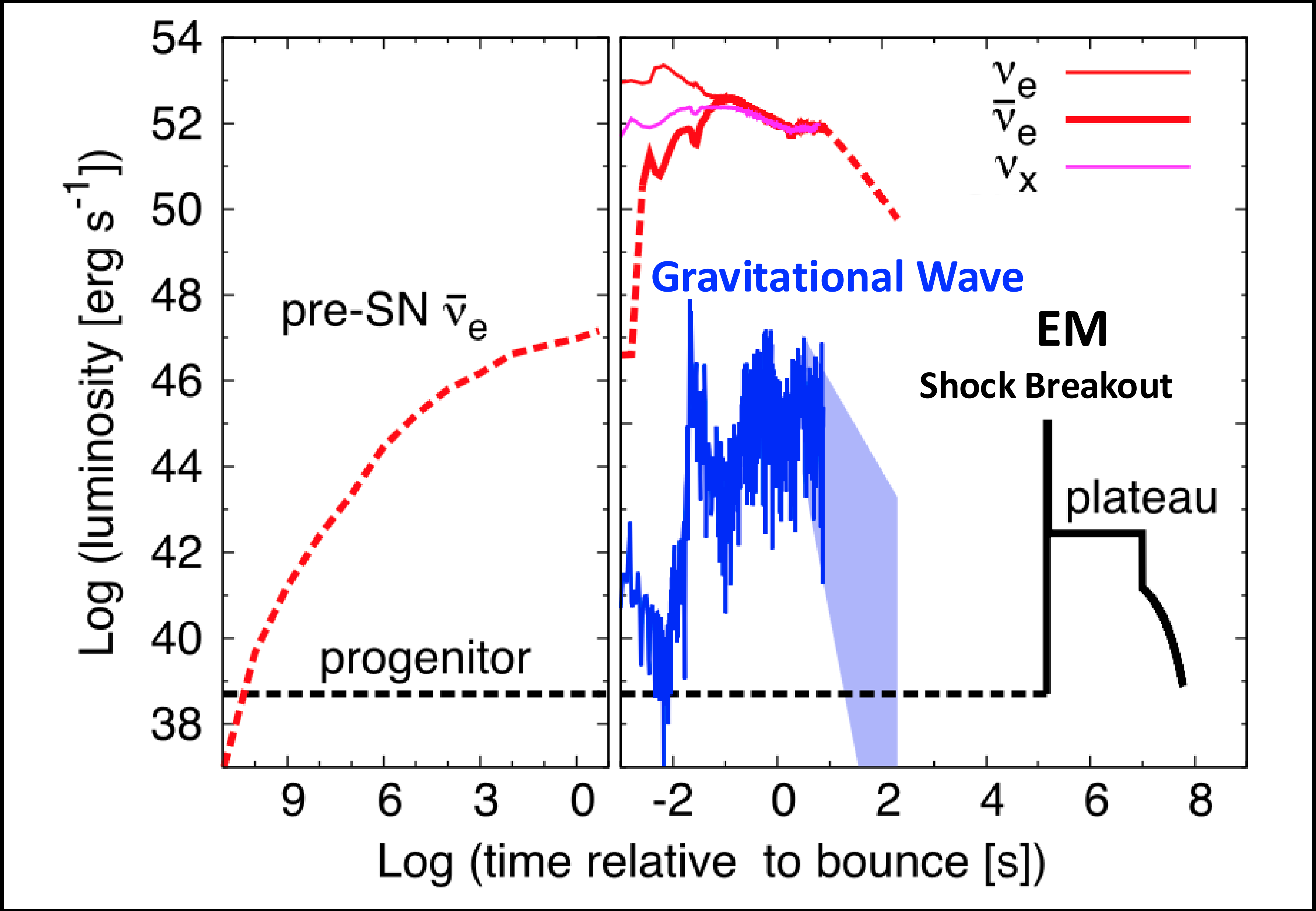
Inverse beta decay (IBD)
$\bar{\nu}_e + p \rightarrow e^+ + n$
Proton/Electron elastic scattering
$\nu_x + p/e^- \rightarrow p/e^- + \nu_x$
…

Electron elastic scattering
IBD (if Gd added in future)
…

$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$
…

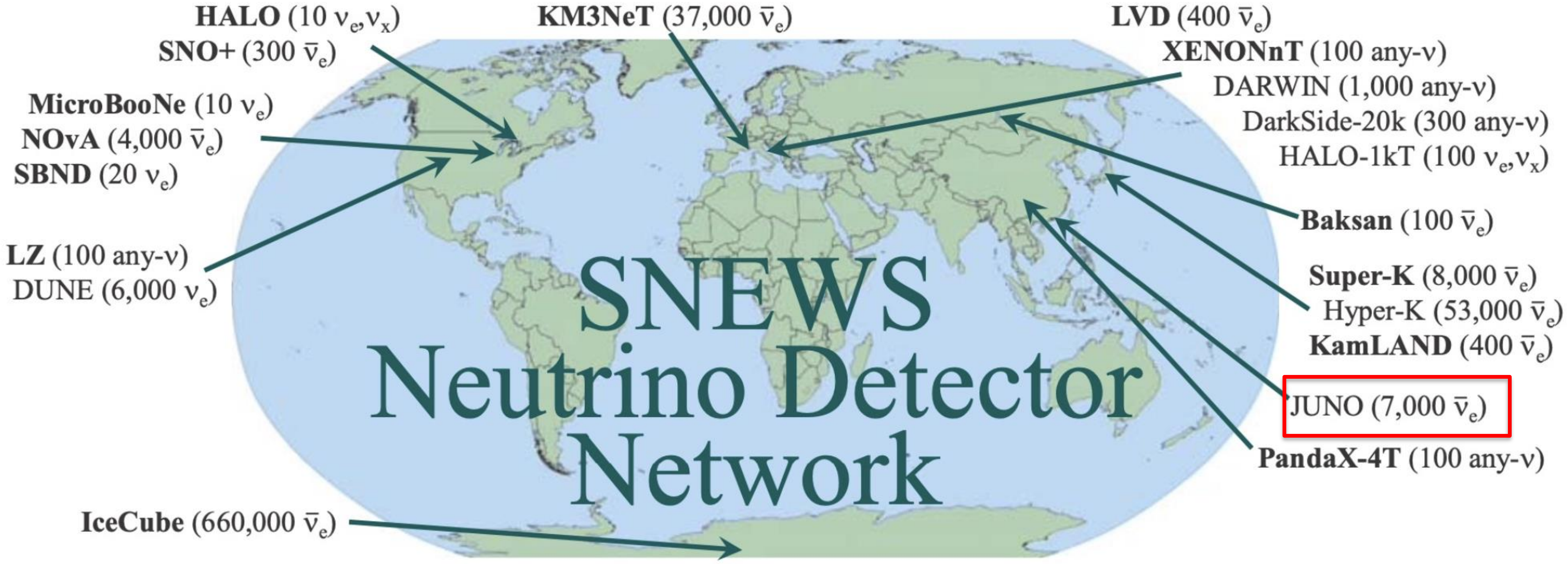
They are complementary in capabilities with different detector technologies.

Supernova Burst Neutrinos
Multi-messenger Astronomy



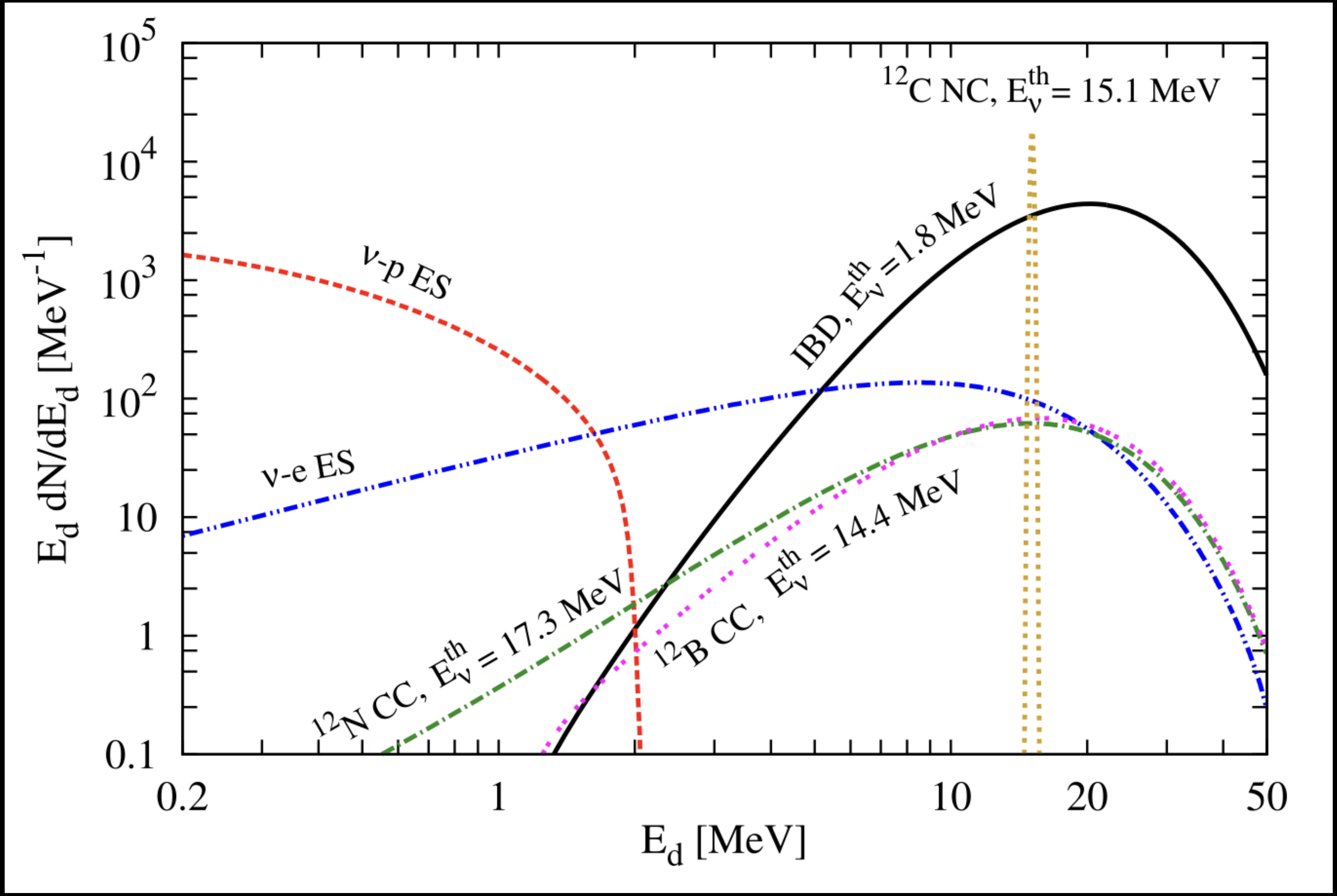
K. Nakamura et al., Mon. Not. Roy. Astron. Soc. 461, 3296 (2016)

Global Network



Supernova Burst Neutrinos
Multiple Detection Channels

For a core-collapse supernova at 10kpc



Inverse beta decay (IBD).
~5000 events
$\bar{\upsilon}_e$ at ~10MeV

Unique for Liquid Scintillator

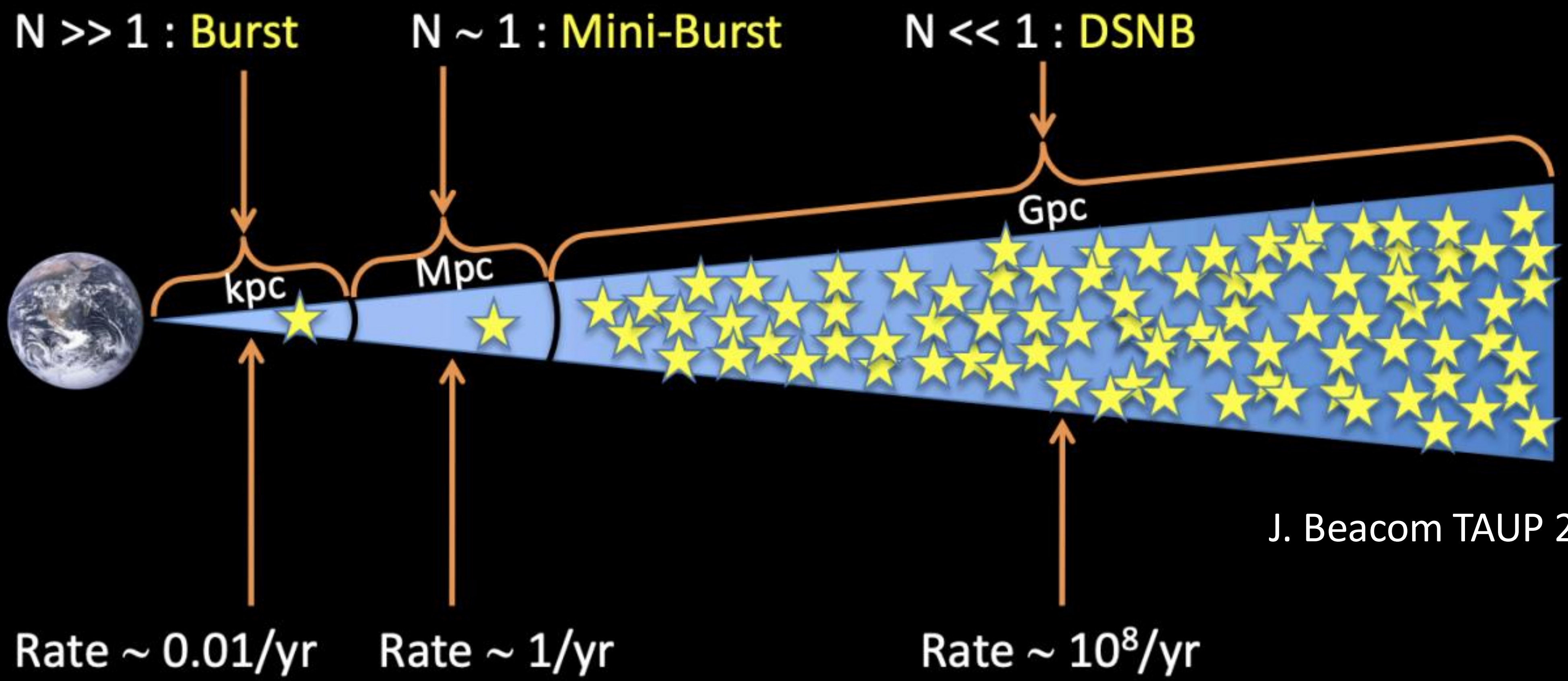
Proton elastic scattering (pES):
~1500 events
all neutrino flavors at lower energy

Electron elastic scattering (eES):
~300 events
all neutrino flavors but larger cross section for υ_e

JUNO Collaboration, J. Phys. G43 (3) (2016) 030401

Diffuse Supernova Neutrino Background (DSNB)

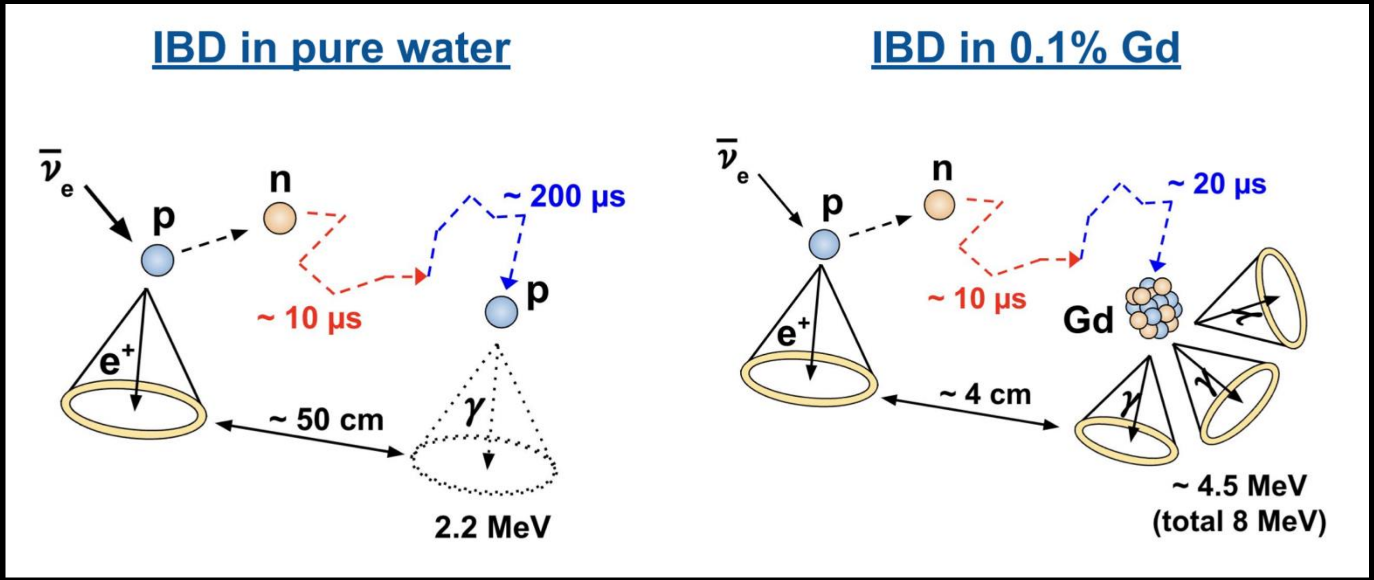
The DSNB is neutrinos (and anti-neutrinos) cumulatively originating from all core-collapse supernovae events throughout the history of the universe.



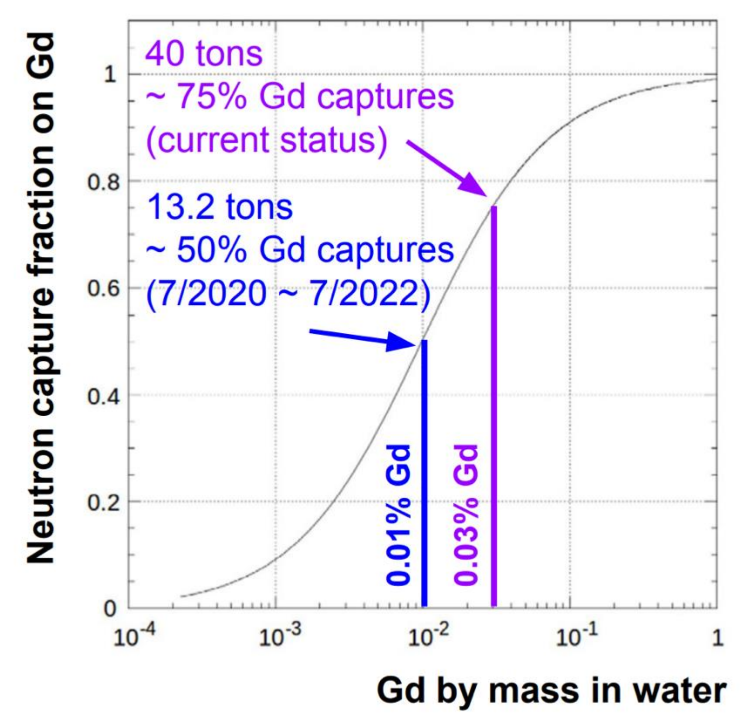
J. Beacom TAUP 2011

Have not been detected yet.

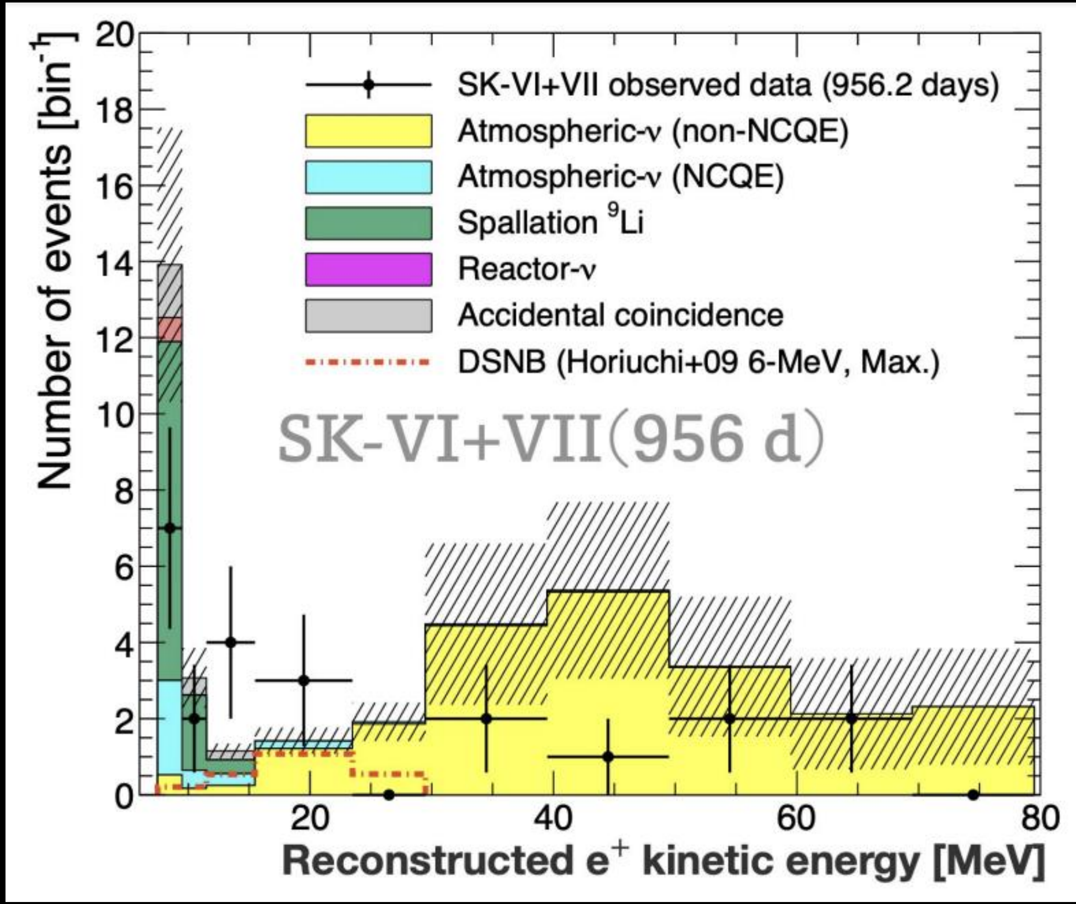
Upgrade of Super-K for DSNB



The Super-K-Gd, involving the addition of gadolinium (Gd) to its water, officially began in July 2020.



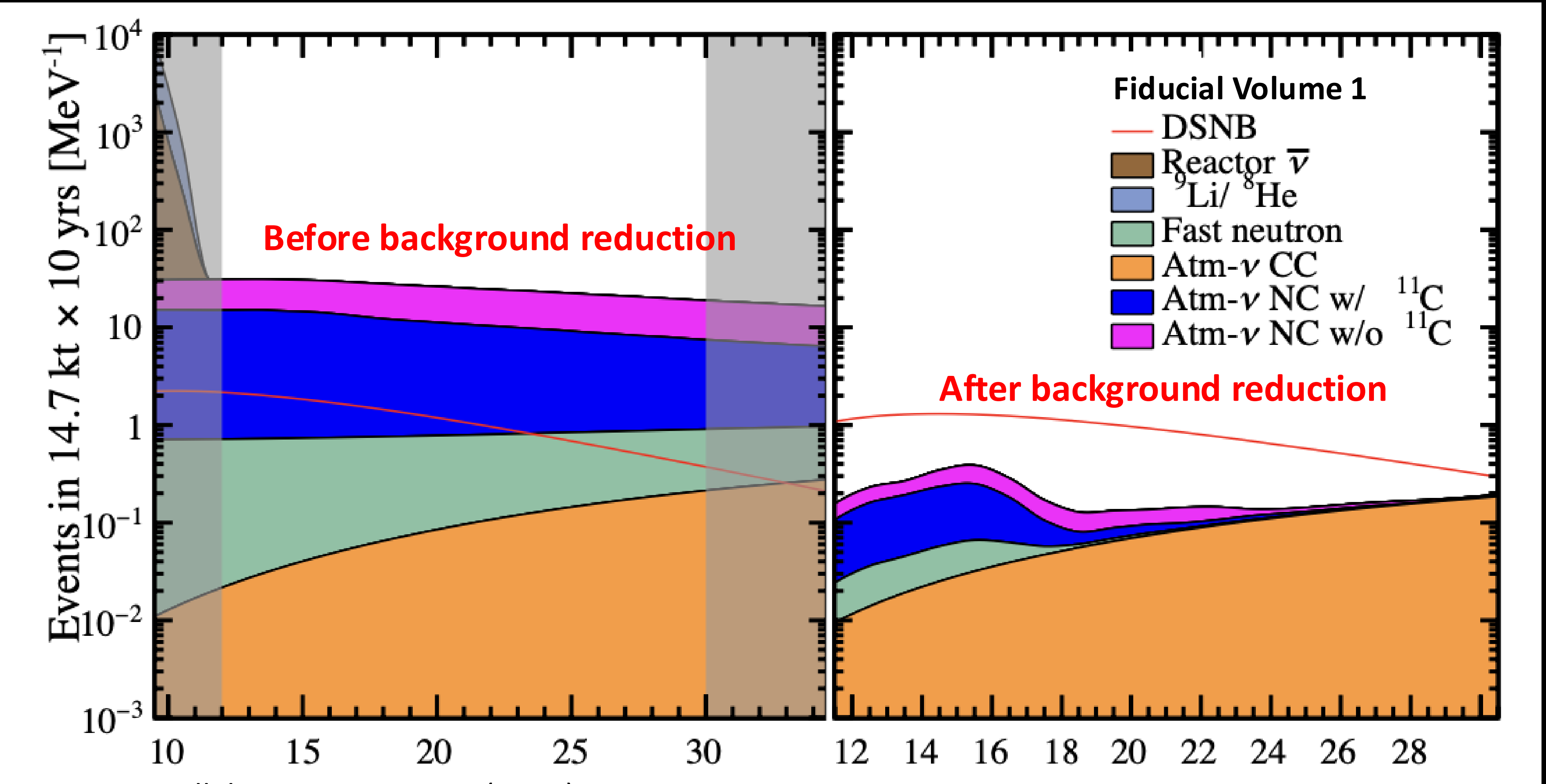
Neutrino 2024



Liquid Scintillator neutron capture efficiency: almost 100%

Detection of DSNB with JUNO

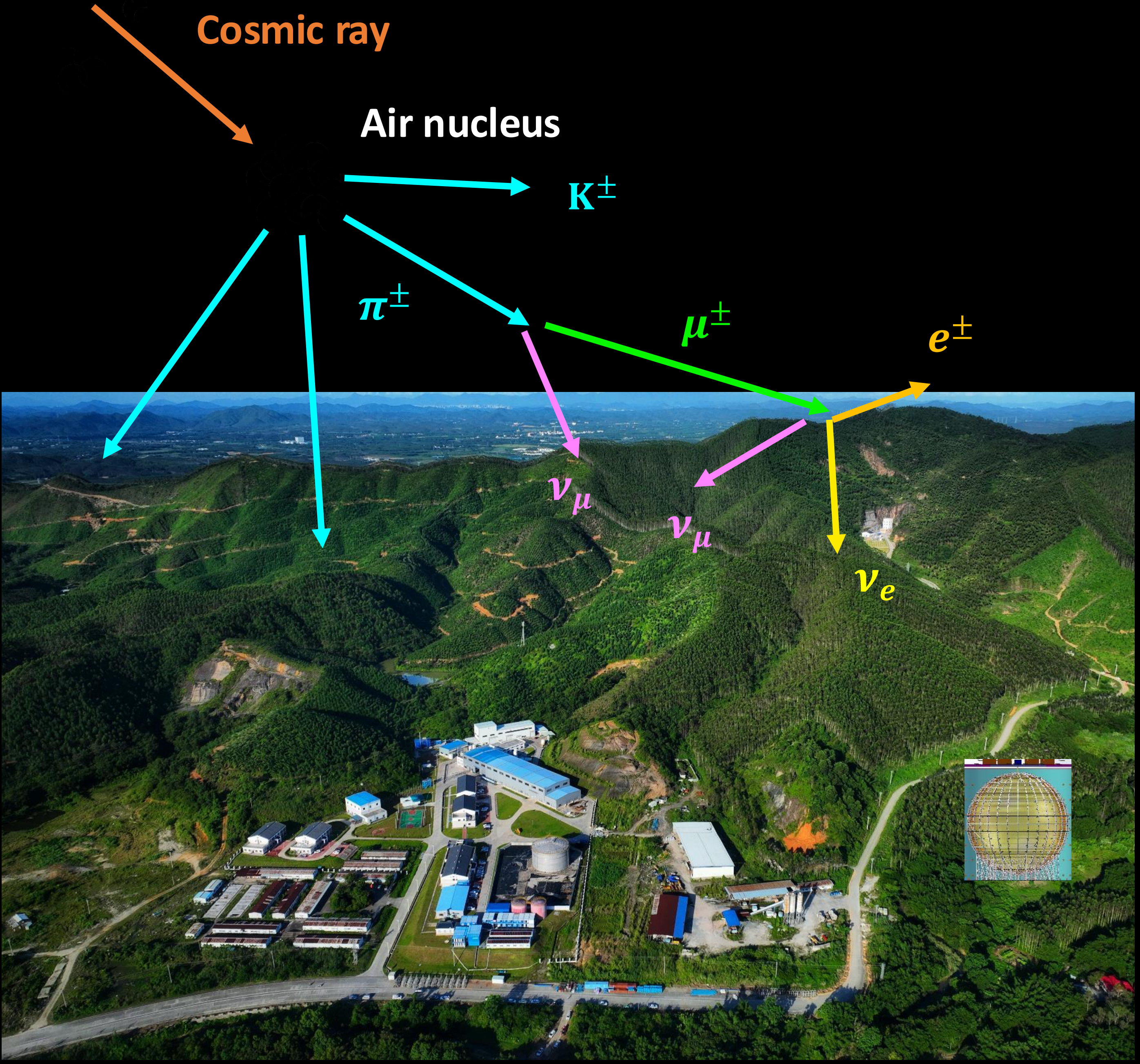
Background Reduction Techniques: Muon Veto, Fiducial Volume Cut, Pulse Shape Discrimination, Triple Coincidence cuts, …

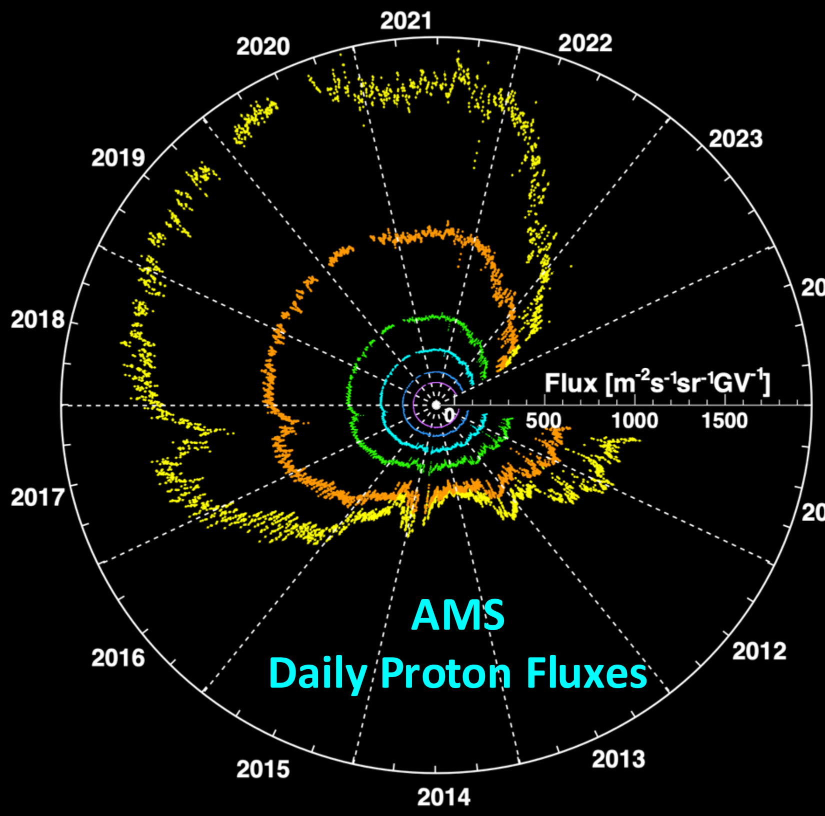


JUNO Collaboration, JCAP 10 (2022) 033

The dominate background for DSNB detection comes from **atmospheric neutrinos interacting via neutral-current (NC) processes** with ^{12}C nuclei in JUNO's liquid scintillator.

One of the Major Backgrounds for DSNB: Atmospheric Neutrinos

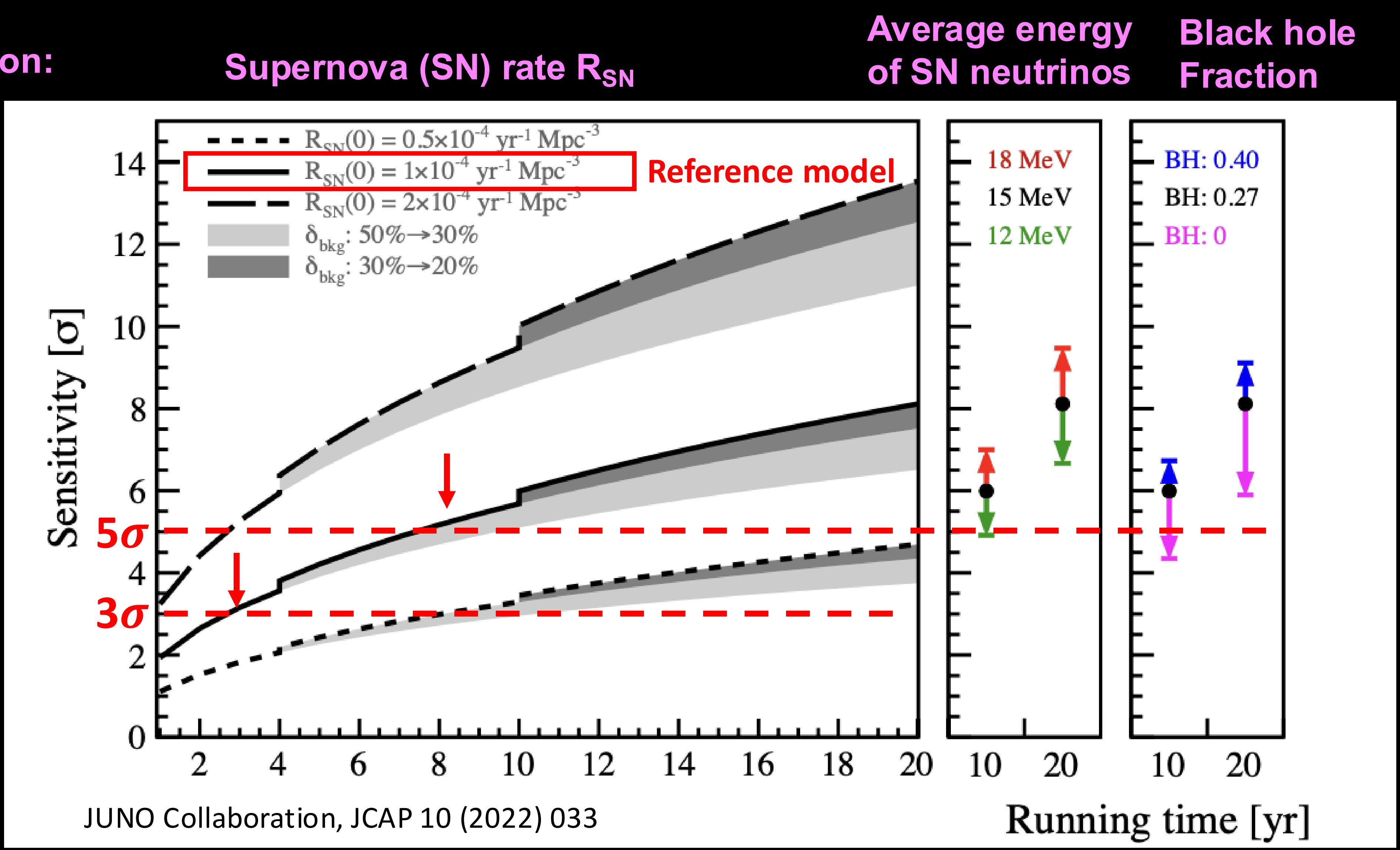




- Data from AMS serves as input to calculate the atmospheric neutrino background.
- Understanding the interactions induced by atmospheric neutrinos is crucial.

Diffuse Supernova Neutrino Background

Key information:



With the reference model: 3σ (3 yrs) and >5σ (10 yrs)

Summary

This is an exciting time to join neutrino research and contribute to discoveries at the frontiers of fundamental physics

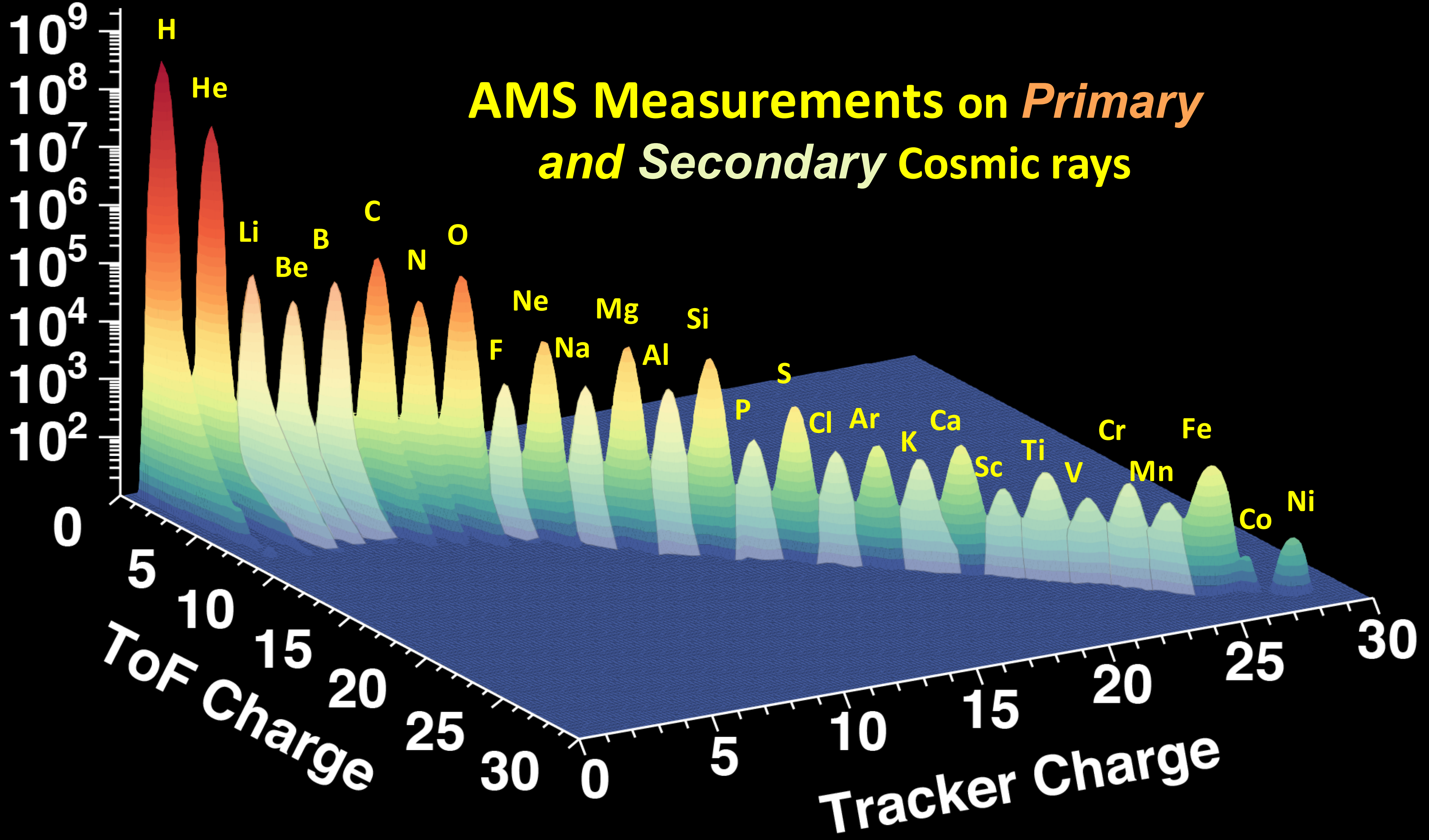
Looking forward to your participation and wishing you enjoy your own scientific journeys in the future!

CERN

江门中微子实验室

Back Up

My Charge Calibration is widely used in the Collaboration



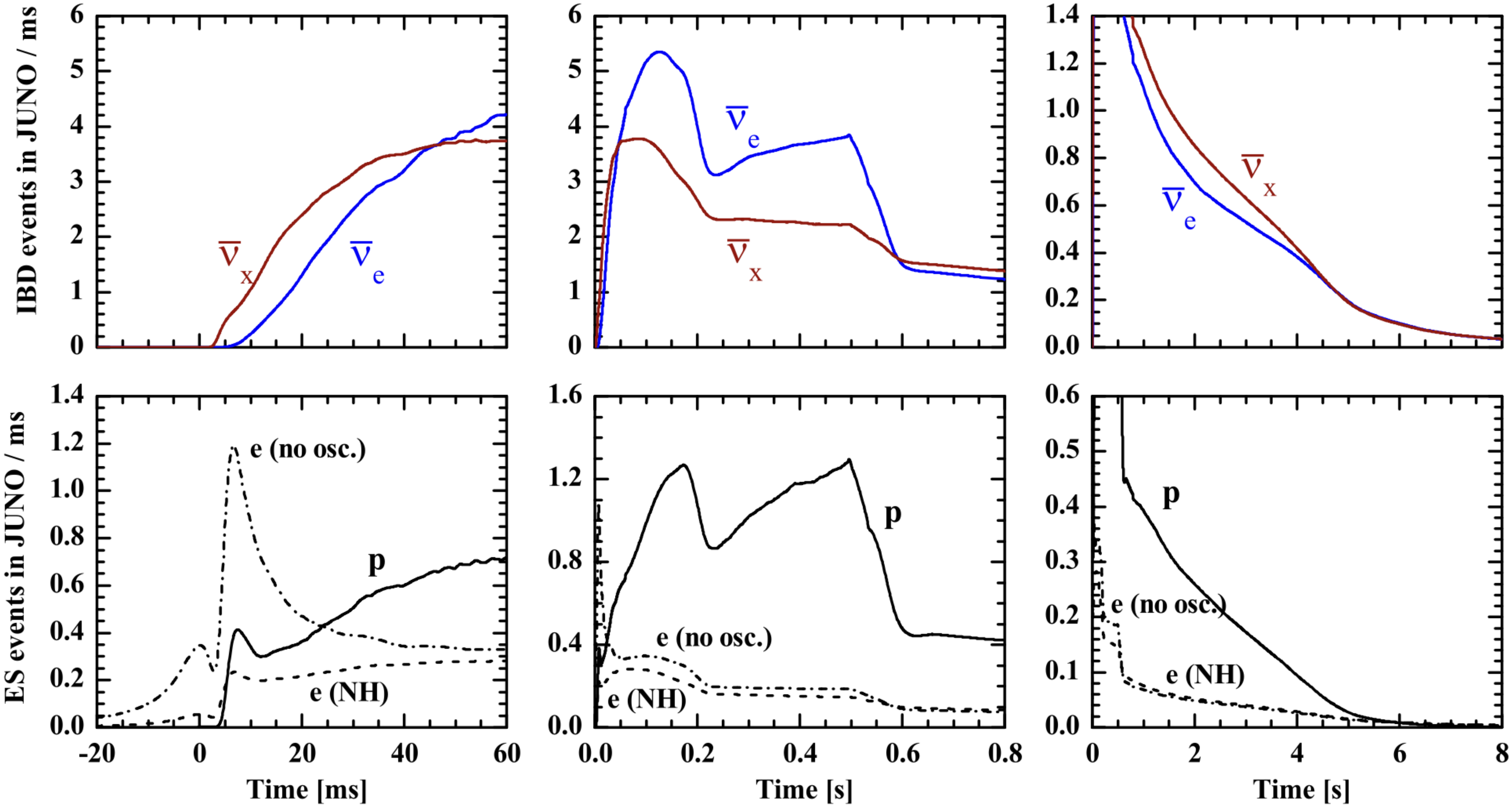

IBD events in JUNO / ms
ES events in JUNO / ms
Time [ms]
Time [s]
Time [s]
$\overline{\nu}_x$
$\overline{\nu}_e$
e (no osc.)
e (NH)
p

Table 10. Numbers of neutrino events in JUNO for a SN at a typical distance of 10 kpc, where ν collectively stands for neutrinos and antineutrinos of all three flavors and their contributions are summed over. Three representative values of the average neutrino energy $\langle E_\nu \rangle = 12$, 14 and 16 MeV are taken for illustration, where in each case the same average energy is assumed for all flavors and neutrino flavor conversions are not considered. For the elastic neutrino–proton scattering, a threshold of 0.2 MeV for the proton recoil energy is chosen.

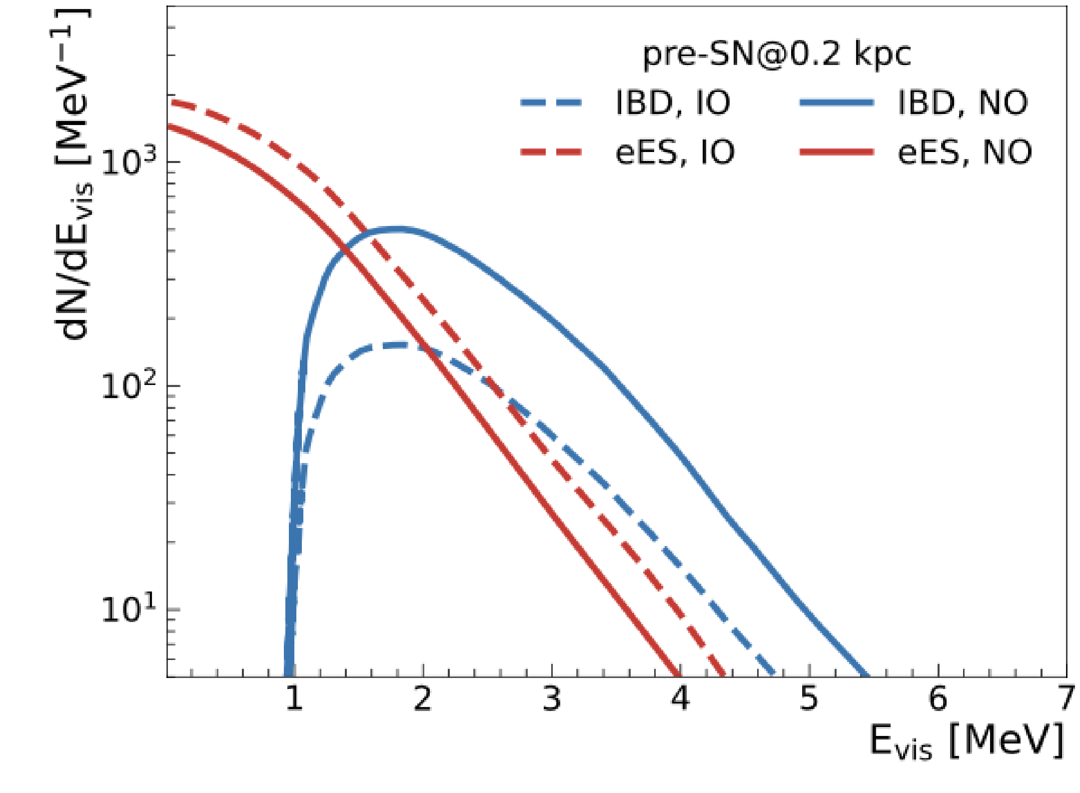
Channel	Type	Events for different $\langle E_\nu \rangle$ values		
		12 MeV	14 MeV	16 MeV
$\overline{\nu}_e + p \rightarrow e^+ + n$	CC	4.3×10^3	5.0×10^3	5.7×10^3
$\nu + p \rightarrow \nu + p$	NC	0.6×10^3	1.2×10^3	2.0×10^3
$\nu + e \rightarrow \nu + e$	ES	3.6×10^2	3.6×10^2	3.6×10^2
$\nu + {}^{12}\mathrm{C} \rightarrow \nu + {}^{12}\mathrm{C}^*$	NC	1.7×10^2	3.2×10^2	5.2×10^2
$\nu_e + {}^{12}\mathrm{C} \rightarrow e^- + {}^{12}\mathrm{N}$	CC	0.5×10^2	0.9×10^2	1.6×10^2
$\overline{\nu}_e + {}^{12}\mathrm{C} \rightarrow e^+ + {}^{12}\mathrm{B}$	CC	0.6×10^2	1.1×10^2	1.6×10^2

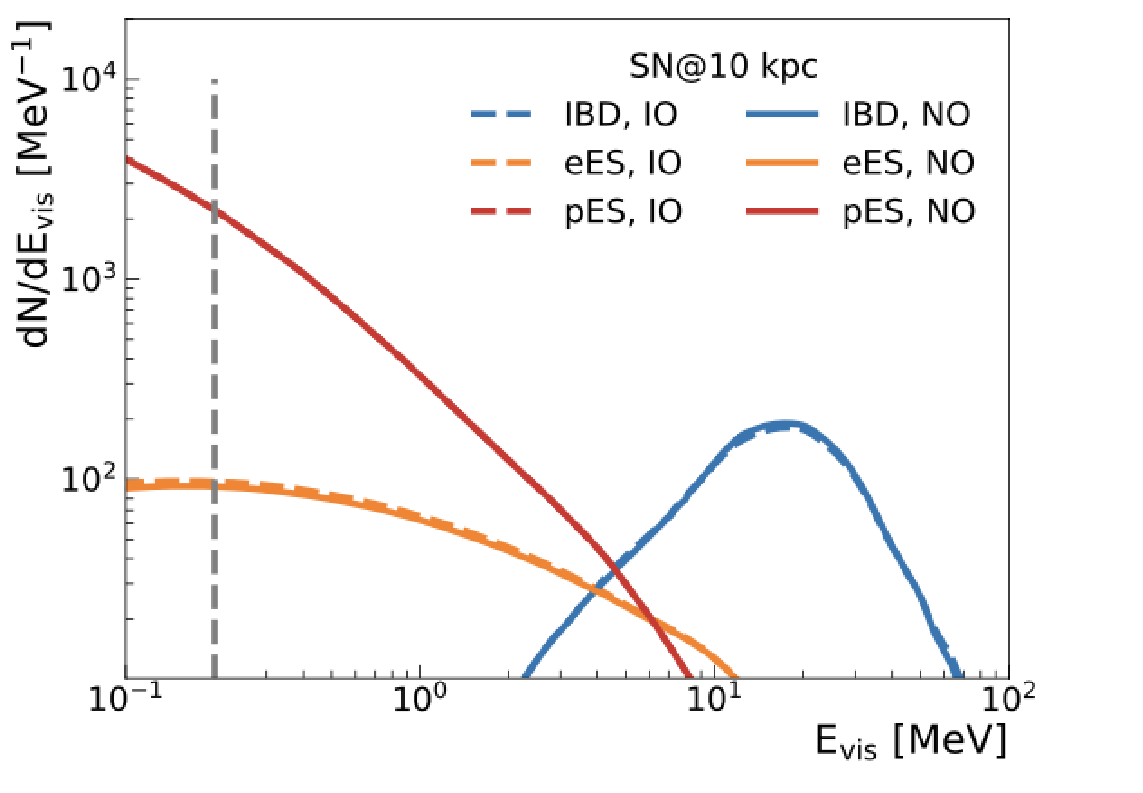
Research Plan 2 a) : Measurement of Supernova Burst Neutrinos

The expected energy spectra

pre-SN neutrinos

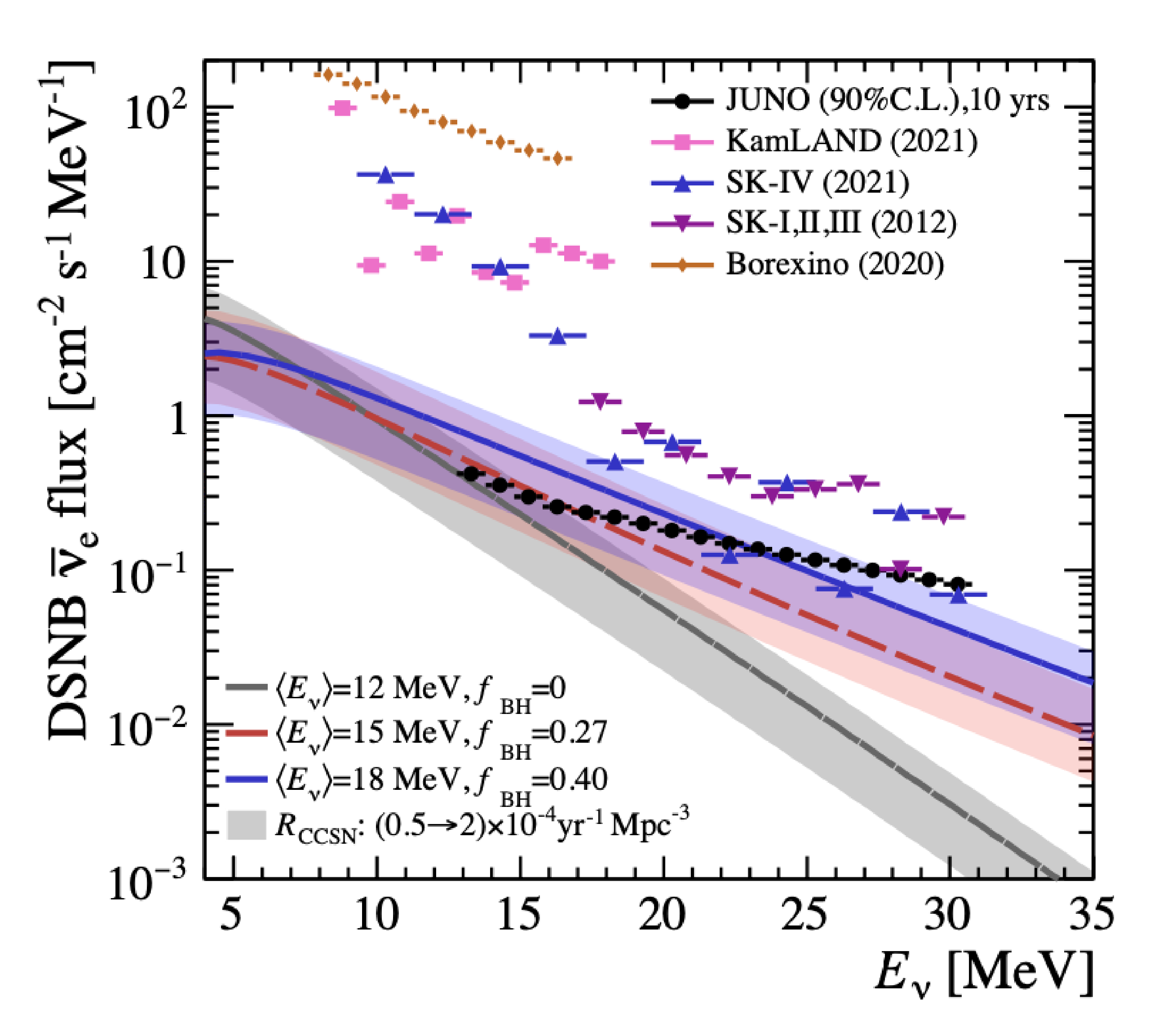
SN neutrinos





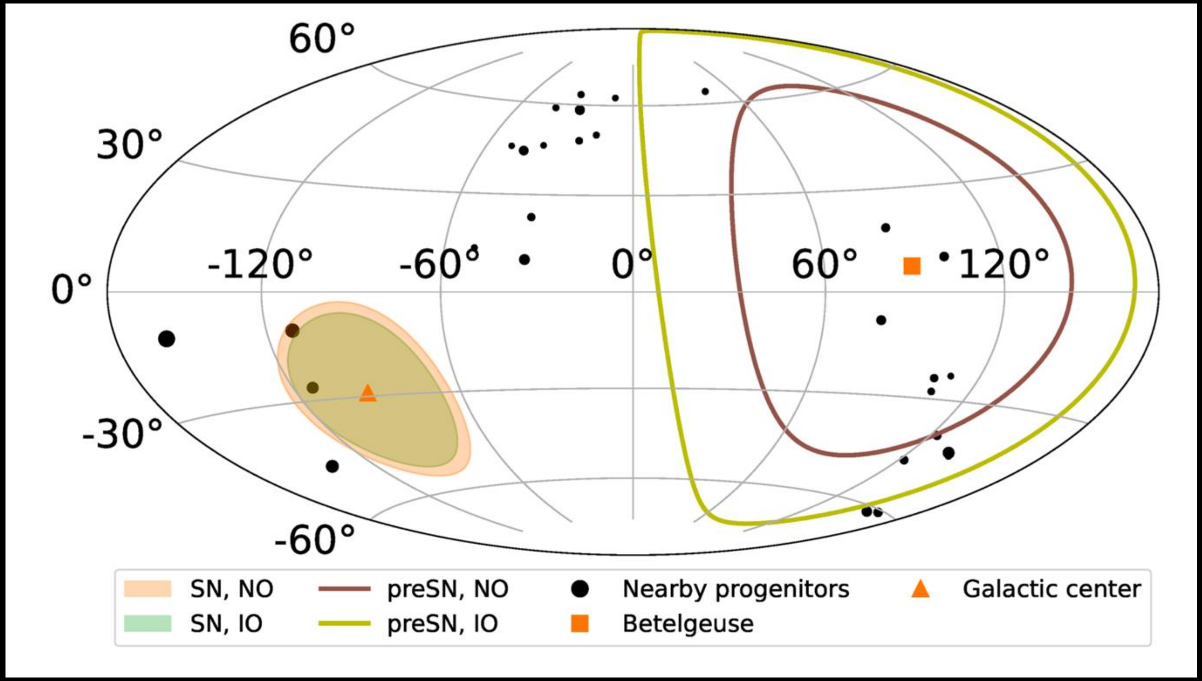
Multiple channels sensitive to all flavors

JUNO Collaboration, JCAP 01 (2024) 057


JUNO (90%C.L.),10 yrs
KamLAND (2021)
SK-IV (2021)
SK-I,II,III (2012)
Borexino (2020)
$\langle E_\nu \rangle$=12 MeV, f_{BH}=0
$\langle E_\nu \rangle$=15 MeV, f_{BH}=0.27
$\langle E_\nu \rangle$=18 MeV, f_{BH}=0.40
R_{CCSN}: (0.5→2)×10^{-4}yr^{-1} Mpc^{-3}
DSNB $\bar{\nu}_e$ flux [cm^{-2} s^{-1} MeV^{-1}]
E_ν [MeV]

Supernova Burst Neutrinos
Directional Information

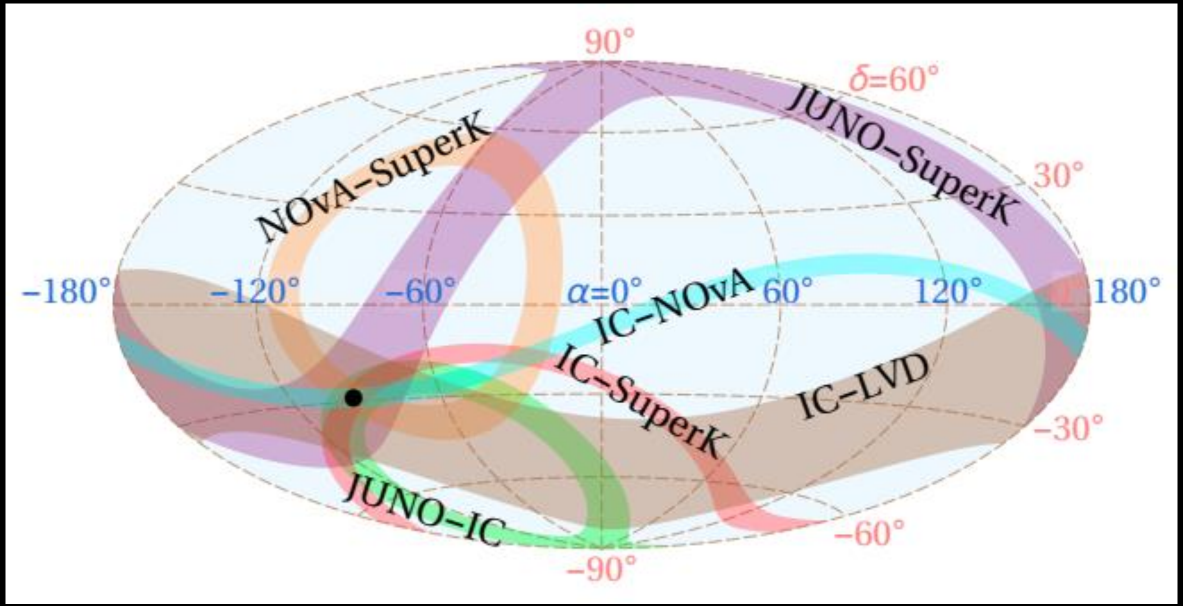
The direction between the IBD prompt positron and delayed neutron capture gives the SN direction.



JUNO Collaboration, JCAP 01 (2024) 057

Triangulation

The time delay between the signal at different detectors define a sky region

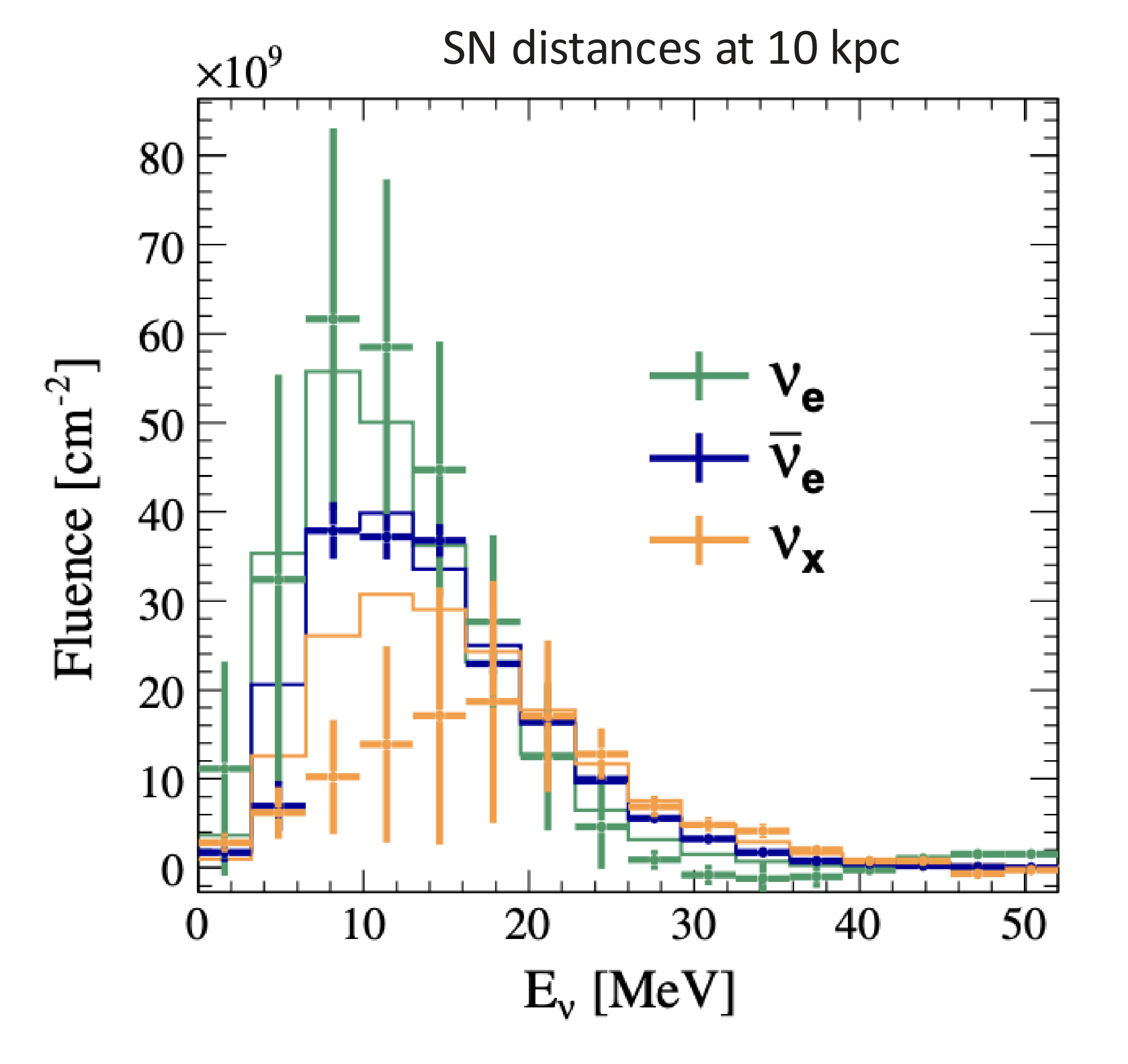


V. Brdar et al., JCAP 04(2018) 025

Betelgeuse-like star pre-SN pointing: 56° (81°), NO (IO) for 15 $M_\odot$.

Typical core-collapse supernova at 10 kpc SN pointing: 26° (23°), NO(IO) for 13 $M_\odot$.

Supernova Burst Neutrinos
Neutrino Energy Spectra

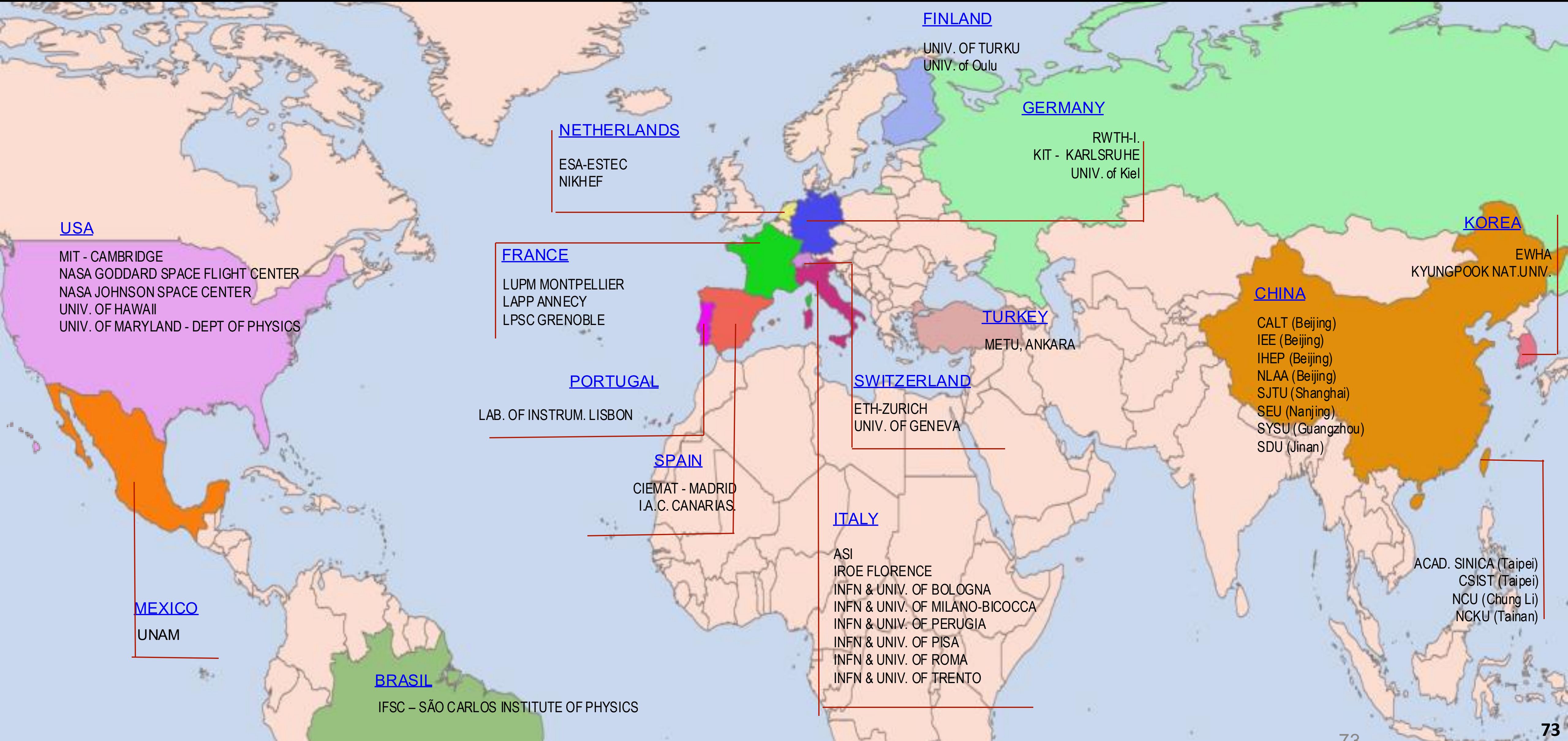


Multiple channels sensitive to all flavors

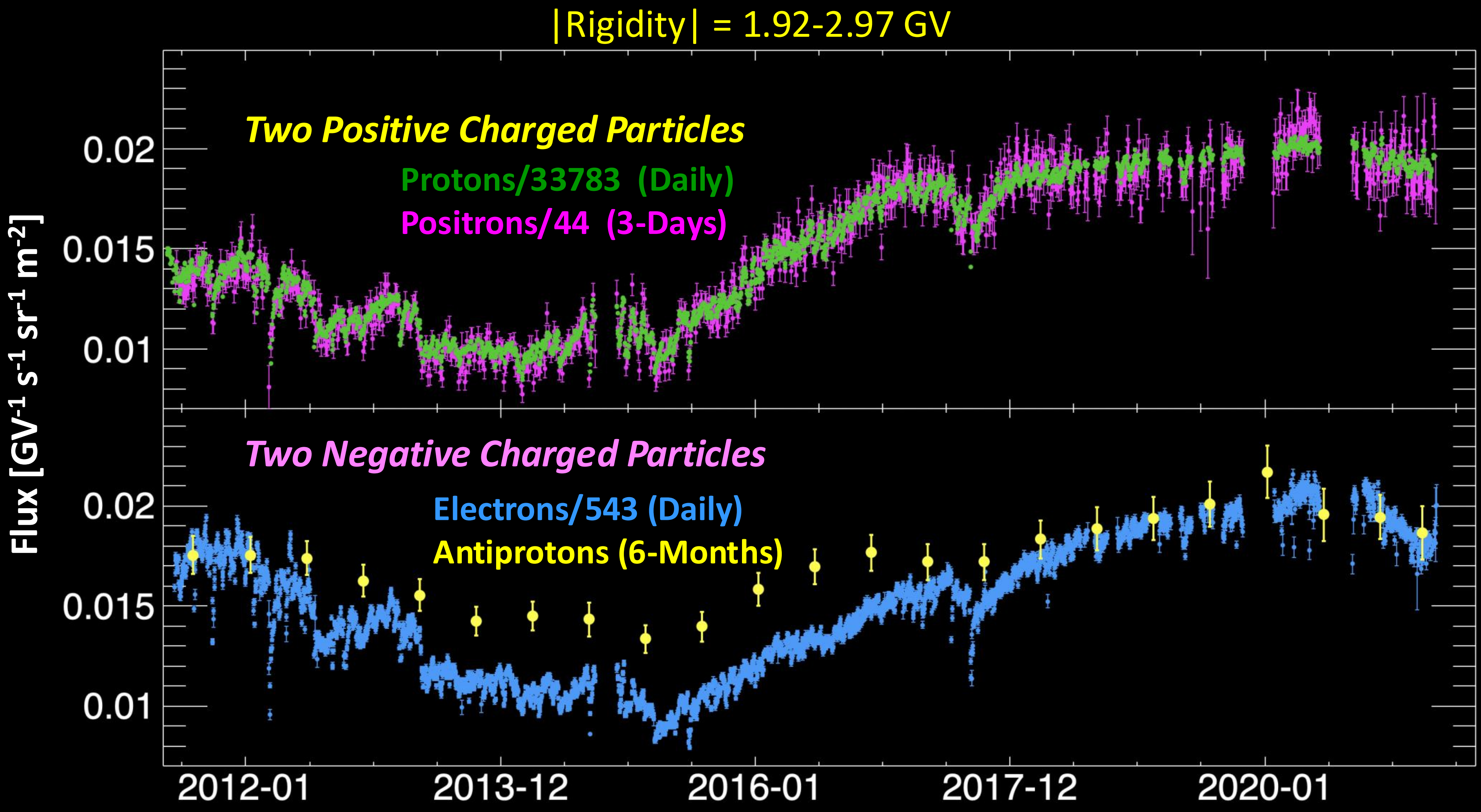
H. L. Li *et al.*, Phys. Rev. D **99**, 123009 (2019).

AMS Collaboration

～600 scientists and engineers from 47 institutions and 15 countries.



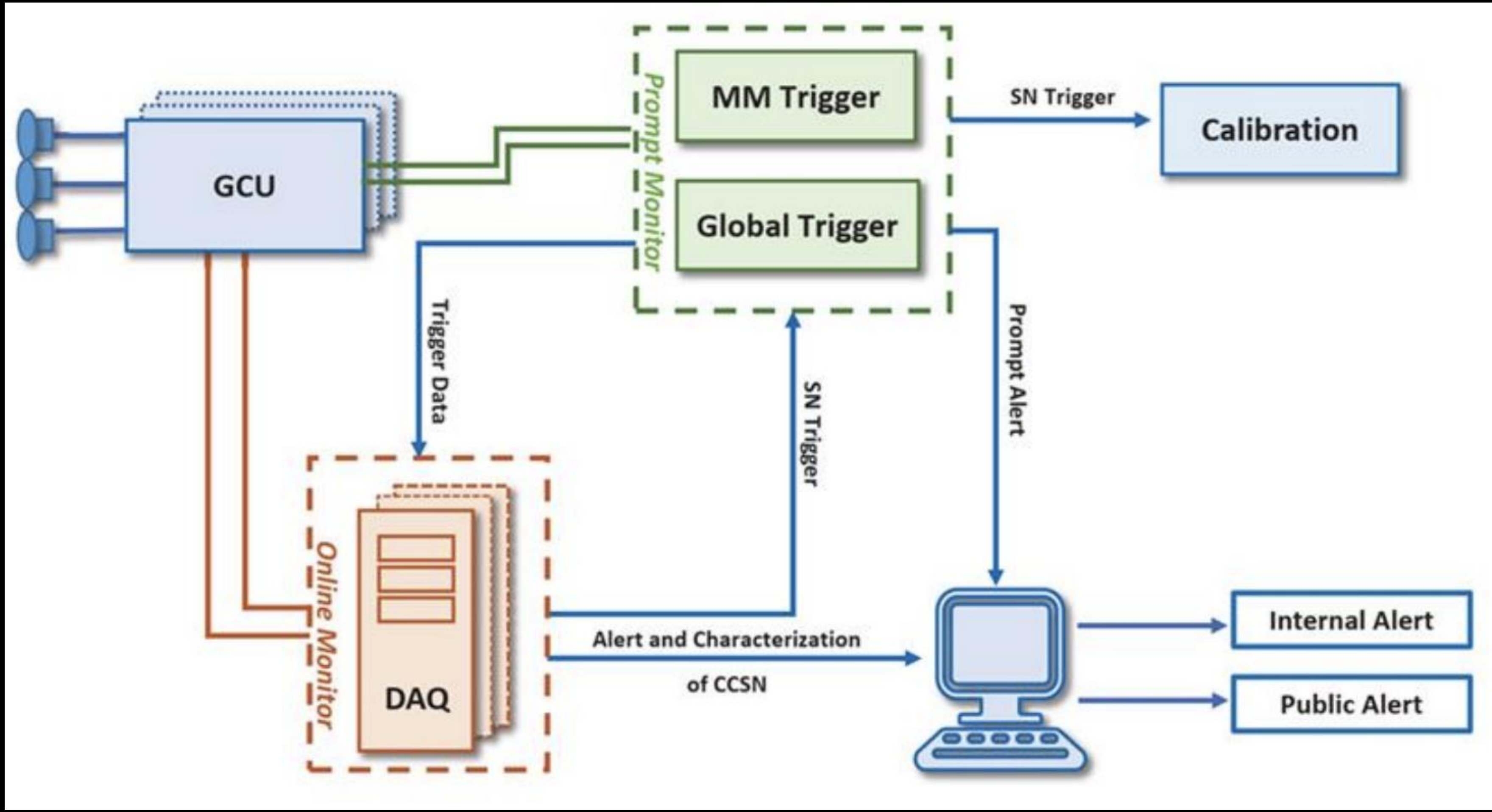
Elementary Particles in the Heliosphere (Protons, positrons, electrons, and antiprotons)



Comprehensive data provide unique input to understand the charge-sign and mass dependence in cosmic-ray modulation inside the heliosphere.

Supernova Burst Neutrinos
Improve Trigger and DAQ

Two major trigger systems in JUNO:
- Global trigger (threshold ~ 0.2 MeV);
- Multi-messenger trigger (threshold ~ 20 keV)



Online Monitor:
Implemented on DAQ.
Based on reconstructed events

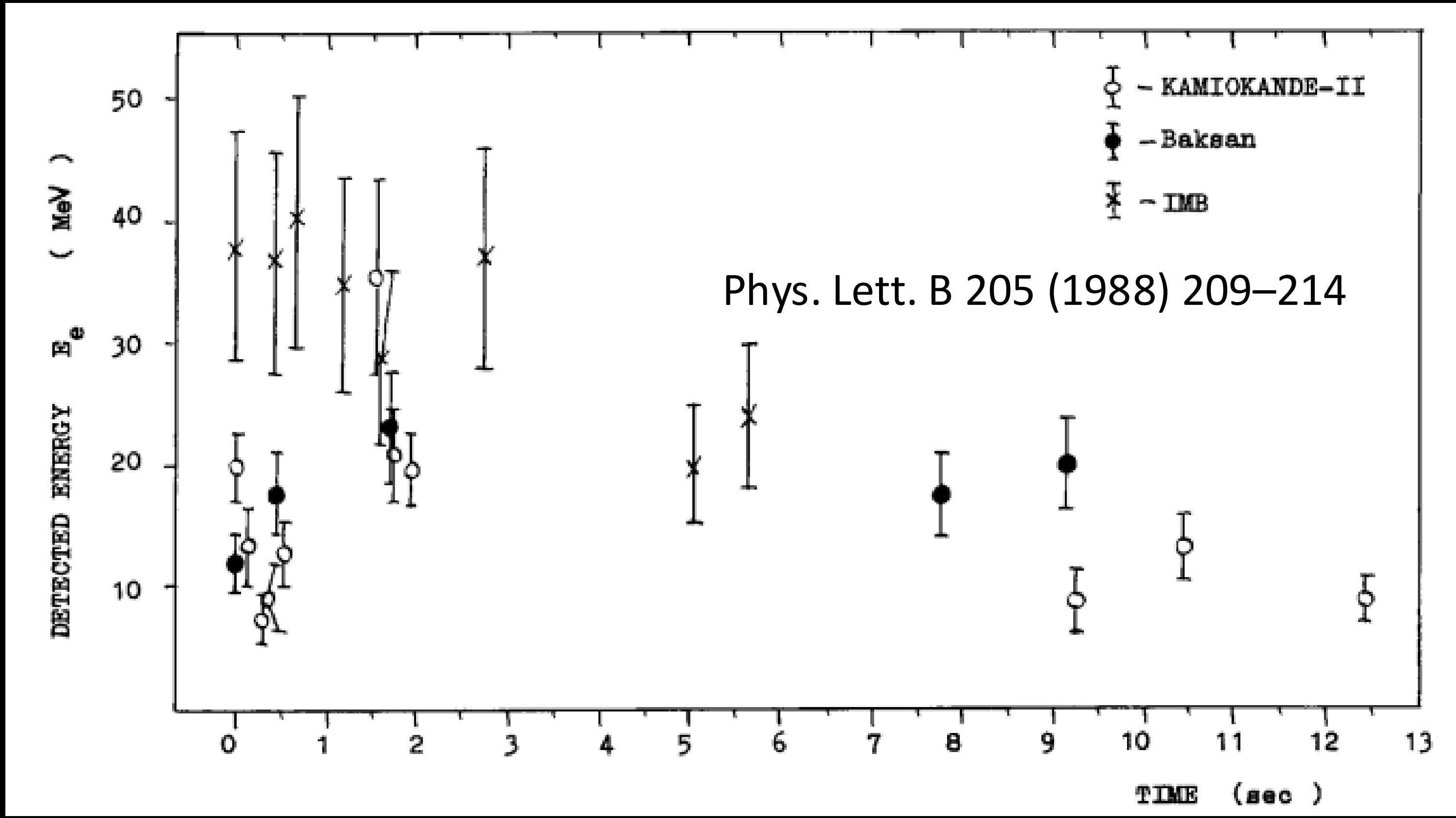
Prompt Monitor:
Implemented on electrics board
Based on trigger

pre-SN:
0.6 - 1.7 kpc with 50% probability,
alert > ~100 hr in advance if 0.2 kpc

SN:
200 - 400 kpc with 50% probability,
alert in 10 - 30 ms if 10 kpc

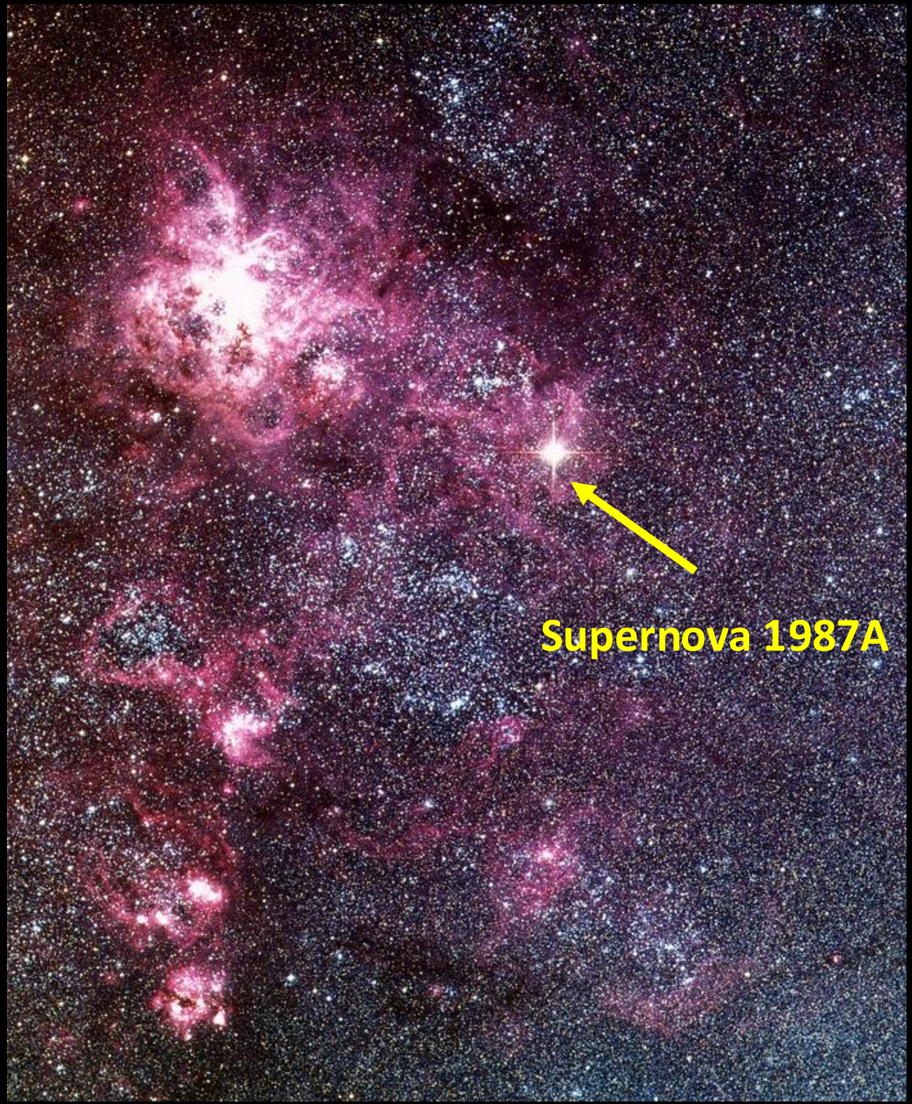
Previous Measurement of Neutrinos from Supernova Burst

Previously, 25 neutrinos were detected from Supernova 1987A by **Kamiokande-II**, **Irvine–Michigan–Brookhaven (IMB)**, and **Baksan** experiments, marking the beginning of neutrino astronomy.



Phys. Lett. B 205 (1988) 209–214

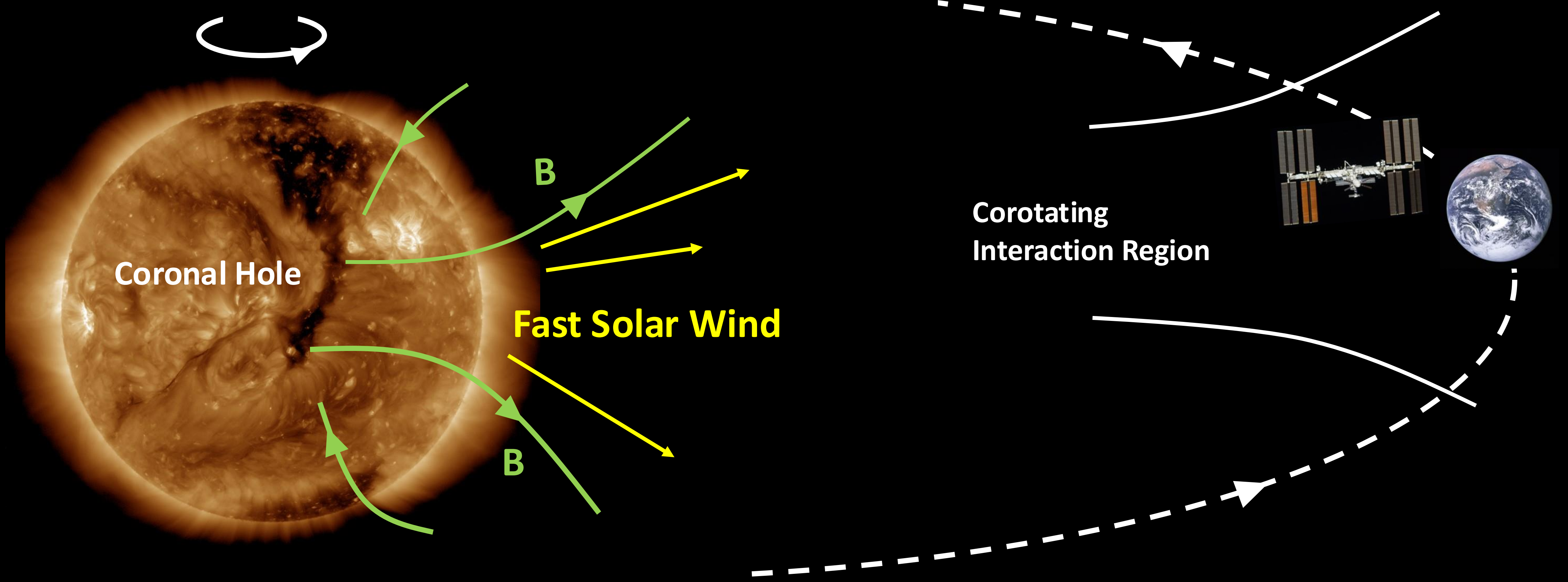
Tarantula Nebula in the Large Magellanic Cloud



Credit: ESO Schmidt Telescope

Cosmic Ray Recurrent Variation in Short Scale

Coronal holes are regions where plasma density and temperature are lower, so they appear darker in images. **Coronal Hole are sources of high speed solar wind affecting Earth.**



Precision measurements of daily cosmic ray fluxes provide unique inputs for the understanding of cosmic rays in the heliosphere.